STOPPING
WATER POLLUTION
AT ITS SOURCE

MISA
Municipal Industrial Strategy for Abatement

BEST AVAILABLE TECHNOLOGY
FOR THE
ONTARIO PULP AND PAPER INDUSTRY

Ontario
Environment
Environnement

92-04883/

ISBN 0-7729-9261-4

BEST AVAILABLE TECHNOLOGY
FOR THE
ONTARIO PULP AND PAPER INDUSTRY

Report Prepared By:

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Report Prepared For:

Water Resources Branch
Ontario Ministry of the Environment

FEBRUARY 1992

PRINTED ON
RECYCLED PAPER
IMPRIMÉ SUR
DU PAPIER RECYCLÉ

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PIBS 1847
log 92-2310-039

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The above authors would like to thank the many individuals who contributed to the preparation of this report. Information and assistance was provided by many people from industry, consulting, governmental, academic and manufacturing organizations as well as mill staff in Ontario, many parts of Canada, US and Europe. Particular recognition is due to Alistair Stewart and Kirsten Vice of the Ministry of the Environment for their efforts to provide the extensive Ministry data in a limited time frame. We would also like to thank the members of the BAT Subcommittee who provided comments and criticism throughout the project.

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EXECUTIVE SUMMARY

This report defines the best technology available for reducing the discharges of pollutants in the effluents from the 27 direct discharge pulp and paper mills in Ontario. It is one step in the Municipal Industrial Strategy for Abatement (MISA) program to virtually eliminate the discharge of persistent toxic contaminants into waterways.

The technology available worldwide was reviewed. The discharge control technologies considered included in-plant measures for reduction of pollution at source, and external effluent treatment. Several **technology trains,** or groups of individual process modifications and/or external treatment processes were developed for each of the four sub-sectors in the pulp and paper industrial sector. Each technology train represents an integrated group of proven systems that could be used to improve effluent quality substantially, and differs in cost and effluent characteristics. These alternative technology trains served as the basis for calculations of process changes and costs to reach various levels of effluent quality.

Since there are many effluent parameters considered, there is no single technology, or even group of technologies, that will minimize the discharge of all pollutants simultaneously. Selection of the best of these trains will therefore depend on the relative importance attached to each pollutant, as well as on a separate analysis of economic achievability by the Ministry.

Best Available Technology (BAT) is defined by the Ministry as the most effective technology which is proven on an industrial scale, or by reliable pilot/laboratory studies, for the reduction of discharges of the pollutants on the Ontario Effluent Monitoring Priority Pollutants List (EMPPL). The definition does not consider cost, but does include reliability, performance, impact on media other than the receiving waters and overall technical feasibility.

The authors investigated a wide range of technologies in North America, Europe, Australia and Japan which were, or were claimed to be, applicable to reducing pollutants discharged in the effluent of pulp and paper mills similar to those in Ontario. In evaluating the available technology, the following aspects were considered:

Modification of the production process to reduce or eliminate formation of pollutants
Chemical substitution
In-plant controls, including the abatement of accidental spills
Best management practices
Water conservation
External effluent treatment technologies
Energy conservation

Reduction of effluents at source

In all alternative technology trains discussed in this report, each of the process modifications for reduction of effluent at source, which was selected for detailed analysis and costing, is exploited to the maximum extent feasible.

For the kraft sub-sector, there is a variety of technologies available which can reduce discharges of pollutants, in many cases more effectively than by external effluent treatment. The principal proven measures are dry debarking, improved pulp washing, extended cooking, oxygen delignification, and substitution of chlorine dioxide for chlorine in the bleaching process.

For the other sub-sectors of the pulp and paper industry, the alternatives for in-plant effluent reduction are more limited, although some potentially very effective measures are at an advanced stage of development.

External effluent treatment

Activated sludge treatment (AST) and the aerated stabilization basin (ASB) processes have been known for many years. Developments in technology and operating practices through the 1980s have demonstrated that better performance is attainable than has been considered normal in the past. While there have been significant evolutionary developments in these fields over the past ten years, there are no radically new external effluent treatment systems that are considered as BAT. The most significant developments have been in operating knowledge. Some of the best performing effluent treatment plants are over 15 years old.

Attainable Effluent Characteristics

In all cases, the technologies evaluated would discharge effluents substantially less contaminated than those defined as "Best Available Technology" (BAT_{US})[1] and "Best Practicable Control Technology" (BPT) by the US Environmental Protection Agency. This is not surprising since the USEPA defined BAT and BPT in the early 1980s, on the basis of data collected in the late 1970s, and a considerable body of pollutant discharge control knowledge has been developed since then[2].

The effluent characteristics defined under BPT and BAT_{US} are primarily BOD and Total Suspended Solids (TSS). They are generally more stringent than the Scandinavian requirements for these pollutants. Scandinavia requirements, and by implication, "BAT" in Scandinavia, concerning organochlorines are more demanding than in the US. The more advanced BAT technologies evaluated in this report would result in lower discharges of organochlorine compounds, AOX, than the current Scandinavian regulations.

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[1] *The abbreviation "BAT" is widely used to refer to an amalgam of the USEPA's BAT and BPT. Ontario uses the term "BAT" to refer to best available technology, without any consideration of economic achievability. The latter is considered independently as part of the process of developing regulations. In this report, "BAT" refers to the Ontario definition, unless stated otherwise.*

[2] *EPA is currently revising its definitions of BAT and BPT. It is expected that more stringent regulations will be in force in the late 1990s.*

Conventional pollutants

The effluent from all alternative technology trains examined would be non-lethal to trout and *Daphnia magna*. Sub-lethal toxicity would be substantially reduced.

Alternatives are presented which could reduce BOD to between 1.1 and 0.4 kg/tonne product, depending on which technology is selected[3]. TSS could be reduced to the range 2.8 to 0.6 kg/tonne. It would be technically feasible to reduce the discharges from any mill to the lower levels indicated, providing the costs and environmental trade-offs such as increased sludge generation and energy consumption are considered acceptable. Attainable discharges for individual mills are presented in the tables at the end of this executive summary.

Organochlorines

Dioxins

The technology for reducing dioxin discharges from bleached kraft pulp mills is becoming quite well known. All the technology trains investigated would reduce the discharges of 2,3,7,8 TCDD below the detection limits specified in the MISA Monitoring Regulations.

The 1990 effluent monitoring program discovered unexpected octa-dioxins in some non-kraft mill effluents. There is no technology known for reducing these discharges, and it is not yet established whether they are environmentally significant.

Adsorbable Organic Halogen (AOX)

Discharges of chlorinated organic chemicals can be reduced by currently proven technology, and five alternative processes were examined which could lower AOX discharges as follows:

Alternative technology trains	LTA
High chlorine dioxide substitution, ASB	1.9
Complete chlorine dioxide substitution, ASB	0.75
Oxygen delignification, ASB	0.6
Extended cooking, ASB	0.5
Oxygen delignification, extended cooking, AST	0.45

All values expressed as kg/tonne bleached kraft pulp.
LTA = Long Term Average, AST = Activated Sludge Treatment, ASB = Aerated Stabilisation Basin.

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[3] *Currently, BOD discharges from Ontario mills are in the range of 3 to 65 kg/tonne product.*

These process alternatives represent only five of a spectrum of many possibilities, most of which can be applied to varying degrees. Five specific implementations were analysed in detail for all the Ontario kraft mills, and are discussed in detail in the report. The data presented above represent the long term average performance for kraft mills bleaching Northern softwood pulps. AOX discharges from mills bleaching hardwood pulps would be lower.

The first alternative, high chlorine dioxide substitution, is already being practiced by many mills, including several in Ontario. The second alternative is being used in at least 20 North American mills and many more mills are presently installing equipment to practice it. Oxygen delignification has been used since 1970, and is currently operating in about 20% of bleached kraft mills in the developed countries, with a number of systems under construction. Extended cooking was introduced in the mid 1980s, and is currently used in several mills, with about twenty additional systems under construction. Equipment corresponding to the last option above is operating in several mills outside Ontario .

Ontario effluent monitoring priority pollutants list

Many of the other substances on the Ontario Effluent Monitoring Priority Pollutants List (EMPPL) were detected only rarely, in trace concentrations, or not at all during the extensive effluent monitoring program which was implemented throughout 1990 in the pulp and paper industry.

Costs of Implementing BAT in Ontario mills

Capital costs

The capital costs of implementing the Best Available Technology in Ontario mills would range from zero, for mills already doing so, to almost $160 million. These costs depend on the size of the mill, site difficulties and the extent of prior investment in effluent discharge control systems.

The high capital costs for pulp mills, particularly the newsprint mills, suggest that at least some of the Ontario mills will follow industry trends seen in most major pulp producing regions, and modernize the pulping operations instead of applying the known in-plant effluent reduction technologies and treating the resulting effluents, as discussed in this report.

In newsprint mills, this would involve abandoning the existing sulphite/groundwood pulping operations and replacing them with modern TMP equipment. The capital costs would be far in excess of those discussed herein, but would reduce total mill operating costs substantially. Prediction of the cost implications of such major mill rebuilds is not within the scope of this report.

Operating costs

Operating and maintenance costs corresponding to the above capital investments would range from negligible to $7 million per year.

The total of the amortized capital cost and operating costs would be $105/tonne product for the kraft mill which would incur the highest costs for the most advanced technology available. Most alternatives for the majority of pulp mills would cost in the order of $40/tonne product. Costs for the paper mills which do not manufacture pulp would generally be about half the latter value.

Costs and attainable effluent discharges for individual mills

Data on the attainable effluent discharges and costs for individual mills are presented in Chapters 7 and 8, for the various alternative technology trains evaluated. The summary tables from these chapters are reproduced on the following pages.

Predicted effluent characteristics and costs for the kraft sub-sector

[This table is reproduced from Chapter 8]

		Boise Fort Frances	CPFP Dryden	CPFP Thunder Bay	Domtar Cornwall	Domtar Red Rock	Eddy Espanola	James River Marathon	K-C Terrace Bay	Malette Smth. Rock
Base case effluent data (1991, *refer to note***)**										
Production rate	t/day	970	965	2,290	726	819	943	425	1,110	297
Bleached product	t/day	573	735	1,279	412	57	943	425	1,110	297
Effluent flow	m^3/day	77,276	91,707	173,931	126,049	95,187	98,577	61,888	95,122	50,664
TSS	kg/day	10,793	5,524	16,000	10,415	6,260	2,745	2,578	4,279	1,512
BOD	kg/day	9,000	3,132	20,793	22,053	15,716	1,689	12,564	1,408	8,310
AOX	kg/day	1,000	2,293	2,683	401	169	841	850	1,931	596
AOX	kg/t	1.7	3.1	2.1	1.	3.	0.9	2.	1.7	2.
Phosphorus	kg/day	136	181	117	43	21	55	40	49	19
TKN	kg/day	742	175	253	355	178	325	191	441	103
Train K1	*Eliminate detectable dioxins*									
Capital cost		$13,127,000	$12,345,000	$38,845,000	$82,764,000	$43,287,000	$15,821,000	$23,456,000	$11,938,000	$24,889,000
O & M costs	$/yr	$2,147,000	$1,560,000	$3,904,000	($3,243,000)	$168,000	$396,000	$1,336,000	$2,042,000	$1,863,000
TSS	kg/day	2,633	2,171	2,290	726	1,843	2,122	956	2,498	666
BOD	kg/day	1,170	965	1,145	363	819	943	425	1,110	296
AOX	kg/day	894	1,392	2,388	235	91	841	805	1,521	438
AOX	kg/t	1.56	1.89	1.87	0.57	1.59	0.89	1.89	1.37	1.47
Phosphorus	kg/day	47	39	40	29	33	38	17	44	12
TKN	kg/day	527	434	500	363	369	424	191	500	133
Train K2	*Eliminate molecular chlorine*									
Capital cost		$26,425,000	$18,964,000	$38,845,000	$84,462,000	$48,454,000	$35,522,000	$31,166,000	$17,281,000	$24,889,000
O & M costs	$/yr	$2,932,000	$3,047,000	$5,845,000	($2,833,000)	$530,000	$2,007,000	$2,661,000	$3,314,000	$2,199,000
TSS	kg/day	2,183	2,171	2,290	726	1,843	2,122	956	2,498	666
BOD	kg/day	970	965	1,145	363	819	943	425	1,110	296
AOX	kg/day	279	479	954	190	20	350	294	627	168
AOX	kg/t	0.49	0.65	0.75	0.46	0.35	0.37	0.69	0.56	0.56
Phosphorus	kg/day	39	39	40	29	33	38	17	44	12
TKN	kg/day	437	434	500	363	369	424	191	500	133

AOX data refers to the production rate of bleached pulp.
Effluent data for "1991" refers to calculated characteristics after projects which were physically committed before April 1991 are completed.
All effluent data shown above are long term averages.
Costs shown in parentheses are negative.

(Table continued on next page)

Predicted effluent characteristics and costs for the kraft sub-sector *(continued)*

		Boise Fort Frances	CPFP Dryden	CPFP Thunder Bay	Domtar Cornwall	Domtar Red Rock	Eddy Espanola	James River Marathon	K-C Terrace Bay	Malette Smth. Rock
Train K3	*Eliminate molecular chlorine (including oxygen delignification)*									
Capital cost		$37,449,000	$33,789,000	$63,936,000	$93,102,000	$45,414,000	$35,522,000	$41,076,000	$45,317,000	$31,665,000
O & M costs	$/yr	$1,828,000	$1,878,000	$2,355,000	($3,471,000)	$429,000	$2,007,000	$1,872,000	$1,005,000	$1,527,000
TSS	kg/day	2,183	2,171	2,290	726	1,843	2,122	956	2,498	666
BOD	kg/day	970	965	1,145	363	819	943	425	1,110	296
AOX	kg/day	183	356	767	148	0	350	234	476	123
AOX	kg/t	0.32	0.48	0.6	0.36	0.	0.37	0.55	0.43	0.41
Phosphorus	kg/day	39	39	32	29	33	38	17	44	12
TKN	kg/day	437	434	400	363	369	424	191	500	133
Train K4	*Eliminate molecular chlorine (including extended cooking)*									
Capital cost		$73,098,000	$74,744,000	$125,362,000	$116,629,000		$119,876,000	$65,255,000	$97,451,000	$52,219,000
O & M costs	$/yr	($1,877,000)	$559,000	($602,000)	($6,485,000)	(Train 4 is not	($1,947,000)	($2,208,000)	($4,833,000)	$1,316,000
TSS	kg/day	2,183	2,171	2,290	726	applicable)	2,122	956	2,498	666
BOD	kg/day	970	965	1,145	363		943	425	1,110	296
AOX	kg/day	160	315	647	100		216	148	446	109
AOX	kg/t	0.28	0.43	0.51	0.24		0.23	0.35	0.4	0.37
Phosphorus	kg/day	39	39	28	29		38	17	44	12
TKN	kg/day	437	434	350	363		424	191	500	133
Train K5	*Eliminate molecular chlorine (including oxygen delignification and extended cooking)*									
Capital cost		$113,042,000	$119,163,000	$153,260,000	$129,433,000		$146,699,000	$85,586,000	$158,633,000	$69,025,000
O & M costs	$/yr	$3,494,000	$7,705,000	$3,691,000	($4,449,000)	(Train 5 is not	$6,896,000	$1,234,000	$1,113,000	$4,129,000
TSS	kg/day	970	965	2,290	726	applicable)	943	425	1,110	296
BOD	kg/day	485	483	1,145	363		472	213	555	148
AOX	kg/day	130	297	568	72		216	110	313	93
AOX	kg/t	0.23	0.4	0.44	0.18		0.23	0.26	0.28	0.31
Phosphorus	kg/day	39	39	28	29		38	17	44	12
TKN	kg/day	485	483	350	363		472	213	555	148

AOX data refers to the production rate of bleached pulp.
Effluent data for "1991" refers to calculated characteristics after projects which were physically committed before April 1991 are completed.
All effluent data shown above are long term averages.
Costs shown in parentheses are negative.

Predicted effluent characteristics and costs for the sulphite/mechanical sub-sector

[This table is reproduced from Chapter 8]

		A-P Thunder Bay	A-P Fort William	A-P Prov.Paper	A-P Iroquois Falls	Boise Kenora	Q & O Thorold	St. Marys Sault Ste. M.	Spruce Falls Kapuskasing
Production and effluents from MISA 1990 sampling program									
Production rate	tonnes/day	472	371	424	801	929	840	506	978
Effluent flow	m^3/day	44,728	25,658	47,206	62,414	47,786	60,740	33,337	75,806
TSS	kg/day	1,904	1,190	1,594	7,625	3,431	2,932	6,012	7,900
BOD	kg/day	27,344	14,023	4,221	55,817	34,889	1,134	5,701	31,681
Phosphorus	kg/day	9	11	4	33	14	25	25	25
Total Kjeldahl Nitrogen	kg/day	77.3	75.1	55.1	194.	109.2	181.6	36.9	12.06
Train S1	*Activated sludge treatment*								
Capital cost		$31,075,000	$20,591,000	$17,144,000	$42,646,000	$32,589,000	$3,830,000	$15,550,000	$34,948,000
O & M costs	$/year	$3,934,000	$2,639,000	$1,761,000	$6,170,000	$4,614,000	$96,000	$1,957,000	$4,483,000
TSS	kg/day	472	371	424	801	929	840	506	978
BOD	kg/day	236	186	212	401	465	420	253	489
Phosphorus	kg/day	19	15	17	32	37	25	20	39
Total Kjeldahl Nitrogen	kg/day	236	186	212	401	465	181.6	253	489
Train S2	*Activated sludge treatment plus granular filter*								
Capital cost		$36,637,000	$25,240,000	$22,279,000	$50,912,000	$41,831,000	$12,397,000	$21,408,000	$44,555,000
O & M costs	$/year	$4,067,000	$2,795,000	$1,838,000	$6,497,000	$5,118,000	$462,000	$2,185,000	$4,896,000
TSS	kg/day	236	186	212	401	465	420	253	489
BOD	kg/day	165	130	148	280	325	294	177	342
Phosphorus	kg/day	9.4	7.4	8.5	16.0	18.6	16.8	10.1	19.6
Train S3	*Activated sludge treatment plus chemically assisted coagulation*								
Capital cost		$34,999,000	$23,890,000	$20,776,000	$48,412,000	$39,016,000	$9,800,000	$19,677,000	$41,622,000
O & M costs	$/year	$4,574,000	$3,194,000	$2,294,000	$7,358,000	$6,117,000	$1,365,000	$2,729,000	$5,947,000
TSS	kg/day	236	186	212	401	465	420	253	489
BOD	kg/day	165	130	148	280	325	294	177	342
Phosphorus	kg/day	9.4	7.4	8.5	16.0	18.6	16.8	10.1	19.6

All effluent data shown above are long term averages.

For Quebec and Ontario Paper Company, train 1 consists of the existing UNOX system with reduced flow. The predicted effluent quality must be considered as indicative only

TKN discharges are omitted for trains 2 and 3 due to lack of available data on performance. The values obtained will be somewhat lower than for train 1.

Predicted effluent characteristics and costs for the corrugating sub-sector

		Domtar Trenton	MacMillan Sturgeon Falls
Base Case Effluent Data *(refer to note)*			
Production rate	t/day	327	274
Effluent flow	cu. m/day	4,015	13,698
TSS	kg/day	574	2,633
BOD	kg/day	5,258	19,655
Phosphorus	kg/day	3	28
Total Kjeldahl Nitrogen	kg/day	24	328
Train C1	*Activated sludge system*		
Capital cost		$10,475,000	$16,850,000
O & M costs	$/year	$2,056,000	$2,614,000
TSS	kg/day	88	274
BOD	kg/day	44	137
Phosphorus	kg/day	4	11
Total Kjeldahl Nitrogen	kg/day	44	137
Train C2	*Activated sludge system plus granular filter*		
Capital cost		$12,091,000	$20,565,000
O & M costs	$/year	$2,104,000	$2,765,000
TSS	kg/day	44	137
BOD	kg/day	31	96
Phosphorus	kg/day	1.8	5.5
Train C3	*Activated sludge system plus chemically assisted coagulation*		
Capital cost		$11,665,000	$19,505,000
O & M costs	$/year	$2,198,000	$3,059,000
TSS	kg/day	44	137
BOD	kg/day	31	96
Phosphorus	kg/day	1.8	5.5

Base case effluent data were estimated by the authors to reflect all projects to improve effluent which were physically committed before April 1991.

[This table is reproduced from Chapter 8]

Predicted effluent characteristics and costs for the deinking/board/fine papers/tissue sub-sector

		Beaver Thorold	**Domtar** St. Catharines	**Eddy** Ottawa	**Noranda** Thorold	**K-C** St. Catharines	**K-C** Huntsville	**Trent Valley** Trenton	**Strathcona** Napanee
Production and effluents from MISA 1990 sampling program									
Production rate	tonnes/day	225	161	166	270	108	100	305	178
Effluent flow	m³/day	15,121	10,473	7,599	20,775	7,736	878	3,659	3,869
TSS	kg/day	759	423	560	1,000	59	5	514	243
BOD	kg/day	1,753	1,193	1,176	3,236	324	3	1,517	608
Phosphorus	kg/day	0.9	0.2	0.3	2.0	1.0	0.3	1	1.6
Total Kjeldahl Nitrogen	kg/day	33.2	19.5	30.9	31	19.5	5.8	13.7	39.3
Train F1	*(Refer to note)*	ASB	AST	AST	AST	None	ASB (exists)	ASB	ASB (exists)
Capital cost		$3,395,000	$6,489,000	$6,775,000	$10,652,000	$0	$0	$3,099,000	$500,000
O & M costs	$/year	$335,000	$978,000	$979,000	$1,296,000	$0	$0	$330,000	$53,000
TSS	kg/day	506	161	176	270	59	5	192	203
BOD	kg/day	225	81	88	135	169	3	85	90
Phosphorus	kg/day	9	6.4	7.1	10.8	1.0	0.3	3.4	1.6
Total Kjeldahl Nitrogen	kg/day	101	81	88	135	19.5	5.8	38	41
Train F2	*Activated sludge treatment*								
Capital cost		$7,387,000	$6,489,000	$6,775,000	$10,652,000	$0	$0	$6,591,000	$4,703,000
O & M costs	$/year	$1,036,000	$978,000	$979,000	$1,296,000	$0	$0	$1,007,000	$970,000
TSS	kg/day	225	161	176	270	59	5	85	47
BOD	kg/day	113	81	88	135	169	3	43	23
Phosphorus	kg/day	9	6.4	7.1	10.8	1.0	0.3	3.4	1.9
Total Kjeldahl Nitrogen	kg/day	113	81	88	135	19.5	5.8	43	23

All effluent data shown above are long term averages.
Train 1 uses the aerated stabilisation basins where space is available on the mill site. Otherwise activated sludge treatment is used.
For trains 2, 3 and 4, the process is uniform for all mills, unless no installation at all is required, so the process is not specified in each column.
K-C, St. Catharines mill effluent BOD was reduced as indicated after the 1990 MISA monitoring program by measures initiated by the company

(Table continued on next page)

Predicted effluent characteristics and costs for the deinking/board/fine papers/tissue sub-sector *(continued)*

		Beaver Thorold	Domtar St. Catharines	Eddy Ottawa	Noranda Thorold	K-C St. Catharines	K-C Huntsville	Trent Valley Trenton	Strathcona Napanee
Train F3	*Activated sludge treatment plus granular filter*								
Capital cost		$10,599,000	$9,002,000	$9,462,000	$14,327,000	$0	$0	$8,176,000	$5,735,000
O & M cost	$/year	$1,160,000	$1,067,000	$1,076,000	$1,445,000	$0	$0	$1,054,000	$996,000
TSS	kg/day	113	81	88	135	59	5	43	23
BOD	kg/day	79	56	62	94	169	3	30	16
Phosphorus	kg/day	4.5	3.2	3.5	5.4	1.0	0.3	1.7	0.9
Train F4	*Activated sludge treatment plus chemically assisted coagulation*								
Capital cost		$9,694,000	$8,310,000	$8,717,000	$13,279,000	$0	$0	$7,760,000	$5,477,000
O & M costs	$/year	$1,402,000	$1,240,000	$1,266,000	$1,735,000	$0	$0	$1,146,000	$1,046,000
TSS	kg/day	113	81	88	135	59	5	43	23
BOD	kg/day	79	56	62	94	169	3	30	16
Phosphorus	kg/day	4.5	3.2	3.5	5.4	1.0	0.3	1.7	0.9

All effluent data shown above are long term averages

TKN discharges are omitted for trains 3 and 4 due to lack of available data on performance. The values obtained will be somewhat lower than for train 2.

(Notes)

1 SUMMARY REPORT

1.1 Terms of Reference

The goal of the Municipal Industrial Strategy for Abatement (MISA) program is the virtual elimination of persistent toxic contaminants in municipal and industrial discharges into waterways.

This report describes the Best Available Technology (BAT) for the reduction of pollutants from the 27 pulp and paper mills in Ontario that will be regulated under MISA. The terms of reference for this study exclude the assessment of economic achievability in favour of identifying technologies on the basis of a technical evaluation of demonstrated performance at the discharge point only. Assessment of economic achievability will be carried out by the Ministry of the Environment.

1.1.1 Objectives

To develop an inventory of the best worldwide technology available for the control of effluents discharged from Ontario pulp and paper mills.

To develop an inventory of current technologies used by the 27 Ontario mills for controlling effluent discharges.

To evaluate several **technology trains**, or technical alternatives, that could be applied to Ontario mills in each of the four sub-sectors of the industry, including an assessment of technical feasibility, resulting effluent quality, capital costs and operating expenditures.

1.2 Background

In selecting the "Best"[4] technology it has generally been assumed that reduction of any pollutant is desirable. This is not necessarily the most environmentally desirable discharge level, but is the only logical basis for evaluating effluent discharge control technology, unless the impact of the effluent on the receiving waters and other environmental effects of the processes used to reduce discharges are also considered. Assessment of the environmental impact of different effluent qualities was not within the terms of reference for this project.

Up to five alternative technology trains have been defined for each of the four sub-sectors in the pulp and paper industry, all of which could be considered as BAT. Several emerging technologies are reviewed that could potentially be used within the next few years to reduce effluent discharges below levels currently considered to be Best Available Technology.

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[4] *The term "Best" implies that there is one technically best approach to reducing the discharge of contaminants in any one effluent stream. In practice this is not so. There are many parameters that must be considered to define the quality of an effluent, so it is invariably necessary to compromise between parameters. For example, the biological treatment process that is most effective in reducing discharges of organochlorines is less efficient than others in reducing BOD. The term BAT is so widely used in the environmental protection field that it has been adopted for this report. Refer to the discussion on page 55.*

Product modifications were not considered as BAT, although current trends in the industry suggest that in some circumstances the management of several mills will prefer this approach to comply with the impending MISA regulations, particularly in newsprint mills.

The Ministry's stated policy is to encourage reduction of effluents at source rather than treatment of waste waters. The potential advantages are frequently mentioned, and have been recognized by the industry for many years, and environmental groups currently express considerable interest in them. All Ontario mills have implemented some measures to reduce effluents by in-plant measures, and in some cases these measures have been extensive. However, this technology is advancing rapidly, and no mill is completely up to date in its application.

In the pulp and paper industry it is now possible to eliminate all planned effluent discharges in some board mills which do not have to produce a white product. More significantly, technologies are emerging which are applicable to the predominant sources of effluents in the pulp and paper sector (kraft and mechanical pulping sub-sectors) which could eliminate over 90% of most of the currently discharged contaminants. However, these latter technologies are not yet fully proven[5], so the technology trains evaluated in this report include biological waste water treatment, which is the only proven approach to attaining non-lethal[6] effluent and very low discharges of BOD.

Technology to reduce effluent at the source is generally known in the pulp and paper industry as "in-plant" technology. This is synonymous in concept with "Pollution prevention at source", and "Discharge control at source". Process modifications to reduce effluents at source are being developed quite rapidly, particularly with respect to control of organochlorine discharges from bleached kraft pulp mills. This report includes the most recent information available to the authors, with data from conferences and personal contacts up to June 1991, but readers are cautioned that some of this information will no-doubt become quite rapidly obsolete.

1.2.1 MISA effluent monitoring program

Traditionally, only a relatively small number of pollutants have been monitored for regulatory compliance in North America. Discharges of many other pollutants have been determined sporadically for regulatory and/or research purposes, but such data were normally available only for short periods or for single mills.

Throughout 1990, the effluents from all 27 direct discharge mills in Ontario were monitored intensively. In addition to the high frequency of the sampling and analysis, the 1990 MISA monitoring program was distinguished by an extensive effort to standardize procedures, and verify quality of flow measurements, sampling and analysis.

In retrospect, there were some limitations in the program. These include failing to record mill operating conditions, particularly production rates, simultaneously with sampling, and the omission of certain toxic substances known to be present in pulp and paper industry effluents due to lack of officially standardized protocols, eg. guiacols and catechols. The program probably cost at least $10 million. However, the database generated by this program represents one of the most complete sources of information available for the pulp and paper mill effluents worldwide.

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[5] *This statement should not discourage regulators from approving applications of innovative technology to substantially eliminate effluents, since several effective processes appear to be approaching industrial scale.*

[6] *"Non-lethal" or "toxic" in this context, and in most references in this report, refers to whether the effluent will fail the standard tests for acute lethality to rainbow trout or daphnia magna. It has little or no relationship to toxicity to humans.*

Data on the Ontario mill effluents used in calculations of costs, and for formulating conclusions in this report, were taken from the first six months of this program. The schedule for production of the report and development of effluent limiting regulations did not allow waiting for the quality assurance/quality control data assessment and report on the full year's data. **The database for the second six months monitoring was scanned and no exceptions were found that would modify the conclusions of this report.**

1.3 Methodology

1.3.1 Development of this report

The **BAT sub-committee** of the MISA Joint Technical Committee was involved in reviewing this report from its inception. This sub-committee includes representatives from the pulp and paper industry, Environment Canada and several branches of the Ministry of the Environment.

The request for proposals for consulting services was developed by the Ministry and approved by the committee, as was the selection of N. McCubbin Consultants Inc. after reviewing proposals from eight consulting organizations from Scandinavia, the US and Canada. The consultant's project manager attended the monthly meetings of the BAT sub-committee from the initiation of the contract in early February 1991 until the last draft of the report was submitted in late July. A current draft of the draft report was made available to the BAT sub-committee for review at each monthly meeting, but was not circulated to all members until 31st May.

The consultant visited a number of mills and regulatory agencies in North America and Europe, and contacted many more to collect data on the best available technologies for reduction of effluents at source, and for effluent treatment. The alternative technology trains to be evaluated were agreed upon with the sub-committee in March 1991, and the committee was kept informed of the mills being visited so that any members could obtain corroborating information as they required, or suggest locations they considered to be of particular interest.

Copies of the mill specific comments in Chapter 4, and in Appendices A and B, were provided to each mill for comment in June and July 1991. Full details of the estimates of capital and operating costs for each mill were provided to each company's MISA representative for review prior to finalizing the report, to minimize errors due to site specific difficulties of which the consultant was not aware.

Useful comments and criticisms were received by the consultant from both industry and government as a result of the above mentioned consultations and circulation of documents. Agreement was reached on technical matters as far as possible. Where there was no agreement, the consultant made the final decision on the content of the report.

1.3.2 Alternative technology trains

After the best available technologies for various aspects of controlling effluent discharges had been identified and documented, cohesive groups, or **trains** of appropriate technologies were developed for each of the four sub-sectors of the Ontario pulp and paper industry. The capital and operating costs for each technology train, and the characteristics of the resulting effluents, were calculated for each individual mill. Most of the technology trains could be applied to each mill in the associated sub-sector, but in some cases site specific conditions made this impractical, or an individual mill had already implemented similar technology.

The technology trains were selected to provide examples of practical ways of implementing the various technologies, as a basis for cost estimates, and a rational basis for recommending which levels of discharge would represent the Best Available Technology. **Each train for a given sub-sector is an independent alternative, and none should be considered as a progression toward another.** In many cases there are alternative ways of achieving similar objectives, and **it is not the authors' intention to suggest that only the technologies described herein should be acceptable to regulators in Ontario.** In particular, emerging environmental protection technology should be encouraged, rather than hindered by the regulations or the procedures of approval of installations.

1.3.3 Sources of information

The authors experience includes environmental work related to the pulp and paper industry in 43 countries, for mills, regulatory bodies, courts and various international organizations. They made considerable efforts through literature searches and personal contacts to ensure that the most advanced technology for control of discharges from pulp and paper mills was considered in developing this report.

Readers will notice that most of the mills on which the authors based conclusions concerning the best demonstrated technology are located in North America. This does not indicate that the mills practicing the best available effluent discharge control technology worldwide are all in North America. Mills with excellent control for aqueous effluents exist in several countries, but the performance of the exemplary North American installations is equal to those overseas, and is better documented by detailed, daily testing in most cases.

Effluent testing procedures used across North America are generally identical to those used in Ontario, for most practical purposes, whereas some European procedures are less stringent, or the data from them are difficult to correlate with similar tests in Ontario. Examples include the Swedish practice of testing for suspended solids with a more open mesh filter than is used in Ontario, or the recording of soluble BOD instead of Total BOD, and the use of BOD_7 in much of the Scandinavian literature and reports to regulatory agencies.

One reference biological treatment system is in an integrated mechanical pulp mill in France, and the others are all in North America. The latter include two in Ontario, E.B. Eddy at Espanola and Kimberly-Clark at Terrace Bay. Several European installations confirmed the feasibility of attaining the effluent characteristics of the reference plants under a variety of conditions by demonstrating equally excellent performance. Most of the exemplary external treatment systems were recently constructed, but the age of the mills varied widely. References for internal process modifications to reduce effluents at source are roughly evenly split between Scandinavia and North America.

1.4 Profile of Ontario Pulp and Paper Industry

There are 27 mills in the pulp and paper sector which discharge treated industrial effluents directly to watercourses[7]. The extent of in-plant measures for reduction of effluent discharges at source, and the degree of effluent treatment varies very widely from mill to mill.

The mills are mostly at least 25 years old. The Kimberly-Clark mill at Huntsville is the only mill built since 1965, when paper industry effluent discharges first became a serious concern in Ontario. Particularly in the case of the older mills, the original date of construction has become almost irrelevant, since most of the original installations have been replaced with more modern equipment in the past 20 years. The CP Forest Products integrated kraft mill in Dryden was substantially replaced in the 1980s, and most of the James River market kraft mill in Marathon has been replaced since 1980. In the sulphite mechanical sector, there has been a trend toward reducing or eliminating sulphite pulp in favour of TMP. The Quebec and Ontario Paper Co mill in Thorold was almost completely replaced in the early 1980s, and the sulphite mill was shut down in 1987. Several mills have installed new or modernized paper machines. Some other companies have invested considerable sums in modernizing their facilities, and a few can be considered as state-of-the-art with respect to effluent discharge control, while others are quite outdated. The only mill which can be considered to discharge extremely low quantities of effluents by worldwide standards is the Kimberly-Clark mill at Huntsville.

All 27 mills have primary effluent treatment, and seven have secondary treatment.

Effluent discharges range from slightly under 1000 m^3/day to 173,000 m^3/day, carrying from 3 to 49,000 kg/day BOD.

Several mills are in the process of implementing effluent discharge control measures[8], including some that were commissioned after the 1990 MISA effluent monitoring program was completed[9]. Eight of the nine bleached kraft mills have invested in measures in the past few years to reduce discharges of organochlorines (AOX), including the PCDD/PCDF[10] group ("dioxins" in colloquial terms). The only mill where 2,3,7,8-TCDD was detected during the first six months of the 1990 MISA effluent monitoring program (James River at Marathon) has since modified the bleach plant to operate without molecular chlorine, which is one of the accepted methods of lowering emissions of 2,3,7,8, TCDD below detectable levels.

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[7] *Several other mills discharge their effluents to municipal sewers. These are not discussed in this report.*

[8] *For example, an oxygen activated sludge effluent treatment system is under construction at the CPFP mill at Thunder Bay.*

[9] *Including capability to bleach kraft pulp without the use of molecular chlorine at James River, Marathon and Boise Cascade in Fort Frances.*

[10] *The term "PCDD/PCDF" is used frequently in this report to refer to the whole family of polychlorinated dioxins and furans, which includes 2,3,7,8 TCDD.*

Four of the nine kraft mills in Ontario have secondary treatment systems, compared to 123 of the 125 kraft mills in the US and 5 of the 15 bleached kraft mills in Sweden.

1.5 Pulp and Paper Manufacturing Processes

Pulp is an intermediate product in the manufacture of paper, and is manufactured in Ontario by a number of quite different processes, with varying effluent characteristics. Kraft and mechanical pulp are the two predominant types of wood pulp produced in Ontario, as well as in the rest of the world. Kraft pulp is usually bleached by molecular chlorine, chlorine compounds and related chemicals, and then dried for sale or used on site for papermaking. Mechanical pulps, produced with a wide degree of chemical assistance and by a variety of mechanical pulping equipment, are used extensively in Ontario for the manufacture of newsprint and to some extent for other products. These processes produce oxygen demanding and toxic substances that may be reduced to very low levels by biological treatment and/or process modifications.

Pulp may also be produced by repulping waste paper, some of which requires deinking. This latter process is a significant source of solid waste, and a minor source of oxygen demanding substances.

1.5.1 Kraft pulp

The kraft process, also known as the sulphate process, is the dominant chemical pulping process in Ontario and the rest of the world. It relies entirely on chemical actions to separate the pulp into fibres, and is most commonly used to produce bleachable grades of pulp. Production of pulp, prevention of effluent discharges at source, and air pollution control are inextricably interrelated. The potential for minimizing effluent discharges at-source is greater for kraft mills than for other types of mill. The major proven process variations of the kraft process developed since 1960 which are environmentally significant are oxygen delignification (1970) and extended cooking (1985). Both are practiced in one Ontario mill. Substitution of chlorine with chlorine dioxide has been developed steadily since the 1960s. It is now quite common to replace all molecular chlorine used in kraft bleaching with chlorine dioxide (100% substitution). Emerging technologies to reduce pollutant discharge from kraft mills include ozone delignification, as well as bleaching with hydrogen peroxide, sodium hydrosulphite and the proprietary *Lignox* process.

1.5.2 Chlorine-free bleaching of kraft pulp

This term is so widely misused that the authors have avoided its use. The terms "molecular-chlorine free" and "chlorine-compound free" are used, as defined in the glossary, to distinguish between the two principal variations of the term "chlorine-free". Both approaches are discussed on pages 34 *et. seq*.

1.5.3 Environmental significance of the brightness of kraft pulps

The possibility of reducing the brightness specifications for kraft pulps was one of the alternative process modifications considered. However, it was rejected since there is evidence that this would not effect discharges of 2,3,7,8 TCDD or TCDF, and that it could perhaps increase total organochlorine discharges. There is no evidence that reducing brightness targets for to-day's kraft pulp bleaching systems would be environmentally beneficial beyond the modest saving in energy involved.

If world market requirements change, and emerging technologies prove successful, then there may be some advantages in manufacturing different pulps, perhaps of lower brightness, but this is not likely to occur within the time frame for promulgating and implementing the currently proposed MISA regulations.

1.5.4 Sulphite pulp

The sulphite pulp mills in Ontario are all integrated with paper mills manufacturing newsprint or similar products. All are high yield, sodium based and operate without recovery of spent cooking liquor, except for Spruce Falls Power and Paper Company Ltd. at Kapuskasing. Whitewater management is the most significant control technique for minimizing the effluent discharge. Newsprint mills in Western Canada, the US and Scandinavia faced with stringent effluent discharge regulations have generally abandoned high-yield sulphite pulping in favour of TMP and sometimes the purchase of small quantities of kraft pulp.

1.5.5 Mechanical pulp

Mechanical pulp is produced in all 8 mills in the sulphite mechanical sub-sector. The process generates effluents that are acutely lethal to fish and *Daphnia magna*, and are a major source of BOD. The only Ontario mechanical pulp mill which has a secondary effluent treatment system discharges a non-lethal effluent, as do all three mechanical pulp mills in Alberta. Some mechanical pulping processes operate without any chemical addition, but most use some caustic and sodium sulphite. Most mills brighten the pulp slightly with hydrogen peroxide and/or sodium hydrosulphite, but none use chlorine compounds to improve brightness. Whitewater management is the most significant control technique for minimizing the effluent discharge at source.

1.5.6 Paper mills

The paper mills in Ontario that are not integrated with a pulp mill are small and generally discharge relatively small quantities of pollutants. White water management is the most significant control technique for minimizing the effluent discharge at source.

1.5.7 Solvent pulping

There are a number of emerging or new pulping processes that are promoted as being environmentally friendly by their supporters. This group includes Organocell, Stake, Alcell, Ester, ASAM, Pollution Free Process, Milox and Oxygen-Alkali. Some of these have been around for 20 years or so while others have just come on the scene. None are demonstrated technologies, and there is no evidence of significant environmental advantages for those which have reached the continuous pilot plant stage of development.

1.5.8 Zero effluent

It is technically feasible to eliminate the discharge of process effluents from some types of board mills.

For other types of mills zero effluent will not be technically feasible in the near future. Nevertheless a substantial reduction in effluent flows and discharges of contaminants is attainable using currently available technology. Considerable progress has been made toward eliminating process effluents, and several emerging technologies are in the industrial pilot plant or full scale construction stage. These include freeze crystallization and/or evaporation of mechanical pulping effluents, as well as ozone delignification and hydrogen peroxide bleaching of kraft pulp.

Technology is now emerging which will probably make it feasible in the near future to design and operate mechanical pulp mills without discharging any process effluents. The costs appear to be in the same order as advanced biological treatment, but operating experiences will be required to confirm feasibility and costs. Operating data from the zero-effluent mechanical pulp mills currently under construction at Chetwynd, BC and Meadow Lake, Saskatchewan, should be available by the end of 1992. If these mills are successful, the currently proven effluent control technology for mechanical pulp mills could become obsolete. In view of the innovative nature of the above mentioned two mills, one can expect that some presently unforeseen technical problems will have to be solved. If this technology is to be applied to newsprint mills, then significant improvements in water recycle within the paper machines would be required, beyond any currently proven or immediately foreseeable technology.

1.6 Current Effluent Characteristics

Conventional waste water parameters are defined as biochemical oxygen demand (BOD_5), Total Suspended Solids (TSS), nutrients (phosphorus and nitrogen) and toxicity to trout and/or *Daphnia magna*.

Many additional parameters are receiving increasing attention from scientists, industry, and regulatory agencies. Organochlorines (AOX) and TCDD/TCDF[11], are well known to the media, and the Ministry's "Effluent Monitoring Priority Pollutants List" **(EMPPL)** includes well over 100 substances considered environmentally significant by the Ministry.

1.6.1 Effluent flows

The flow of effluent from Ontario mills varies from approximately 10 to 175 m^3/tonne product. Ministry policy is to encourage minimal effluent flows, and the technology described in this report is generally based on reducing the larger flows to 50 m^3/tonne product. Lower values are attained in many mills outside Ontario, but these are either greenfield or have worked for many years to reduce flows. **The authors do not intend this to be considered as a recommendation that flows be limited to 50 m^3/tonne** since this value is simply a tool for calculating rational and technically sound values for BAT pollutant discharge loadings.

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[11] *Popularly known as "Dioxins".*

1.6.2 Priority pollutants

The MISA mill effluent characterization program (MISA 1990) and preceding screening analyses determined the concentrations of 135 pollutants in the effluents of the 27 mills listed in Table 3. The first six months of MISA monitoring data have been reviewed in detail, and comments on the results for each mill are summarized in Chapter 4. The data collected were analysed in accordance with "Procedures and Criteria for the Development of MISA Effluent Limits Regulations" (*in* MISA/IRC 1990), which was in the final stages of publication by the Ministry at the time of writing.

1.6.3 Candidate parameters for control

Table 1 below lists the contaminants that the Ministry of the Environment are considering in the development of effluent limits for the MISA Pulp and Paper Sector. These contaminants have been selected based on the selection criteria outlined in the draft Issue Resolution Committee Report on Limit Setting and Data Analysis (MISA/IRC 1990). Based on the procedures outlined in the Issue Resolution Committee Reports, a contaminant is selected if the monitoring data show (at a 95% confidence level) that at least 10% of the data are at concentrations greater than the Regulation Method Detection Level.

Table 1 also provides comments on each parameter and the technologies that will reduce the concentration of the parameter in mill effluent. The right hand columns of the table show the sub-sector in which the parameters were detected.

It should be noted that **the Ministry will make the final selection of the parameters to be regulated.** Table 1 was developed by the authors to provide focus for the subsequent analysis in this report of the technologies for effluent control.

This report addresses the control of discharges of these contaminants in some detail, and very brief comments are summarized in the table. Most of these variables are discussed in further detail in Chapter 4. In many cases, the control technology for one member of a chemical group is quite well known, and is predictable. Reducing the well known substance will normally reduce discharges of similar substances.

Table 1 List of candidate parameters for control

ATG	Variable	Comments	Mill Sub-Sector			
	General waste water variables, discussed on page 113					
01	COD	Biological treatment removes up to approx 40%. Internal measures are generally more efficient in reducing COD.	K	M	C	D
04a	Ammonia plus Ammonium	Must often be added to biological treatment plants in the pulp and paper industry for maximum BOD removal efficiency. Excess controlled by treatment plant operation. Free ammonia is very toxic to fish. Generally, ammonia is of no concern below pH 8.	K	M	C	D
04a	Total Kjeldahl Nitrogen	Reduced by biological treatment. Normally about 8% of it is very persistent and not available to algae.	K	M	C	D
04b	Nitrate + Nitrite	Probably a non-issue in pulp mill effluents, because pulp mill effluent treatment plants have limited nitrogen salts. Can be reduced to atmospheric nitrogen in anoxic zones of a biological treatment plant.	K	M	C	D
05a	Dissolved Organic Carbon (DOC)	As for COD.	K	M	C	D
06	Total phosphorus	Must be added to biological treatment plants for maximum BOD removal efficiency. Excessive concentrations can cause eutrophication of receiving waters	K	M	C	D
07	Specific Conductance	Should generally be high on pulp mill effluents. Low conductivity indicates potential for a successful water conservation program.	K	M	C	D
08	Total Suspended Solids (TSS)	Depends strongly on biological system's performance.	K	M	C	D
08	Volatile Suspended Solids	Closely related to TSS. Can be lower than TSS for paper mills discharging fillers (clay).	K	M	C	D
	Other variables, discussed on pages 114 and 123					
PP1	BOD_5	BOD is a measure of the oxygen consumed in a sample over a 5-day period by the action of microorganisms. Reduced in biological treatment plants. Can be of importance for discharges to receiving waters that are vulnerable to oxygen depletion.	K	M	C	D
PP2	Adsorbable Organic Halogen (AOX)	Formed after use of chlorine chemicals in pulp bleaching. A major fraction of AOX consists of chemically unstable or readily biodegradable materials, which are easily mineralized in any biological treatment plant. Materials which are not mineralized during biological treatment are more persistent in the environment. Approx. 0.1% of AOX is bioaccumulative.	K			D

In Mill Sub-sector column, K= Kraft, M=Sulphite-mechanical, C=Corrugating, D=Deinking/board/fine papers/tissue Sector.

(Table continues next page)

List of candidate parameters for control *(continued)*

ATG	Variable	Comments	Mill Sub-Sector
	Metals, discussed on page 137		
09	Aluminum	Routinely used to reduce COD, AOX and toxicity of effluents. Precipitates with phosphate or sulphide.	K M C D
09	Cadmium	Found up to 140 μg/L. Approximately 70% removed in AST treatment, less in ASB	C
09	Chromium	Found up to 300 μg/L. Approximately 75% removed in AST treatment, less in ASB	K C D
09	Cobalt	Found up to 70 μg/L. Approximately 40% removed in AST treatment, less in ASB	C
09	Copper	Copper salts are generally used in wood preservatives, fungicides and toxic pigments in antifouling agents. Common in raw water. Very toxic to fish. Found up to 290 μg/L. Approximately 70% removed in AST treatment, less in ASB.	K M C D
09	Lead	Found up to 50 μg/L. Some removal in biological treatment	C
09	Molybdenum	Found up to 60 μg/L. Approximately 10% removed in AST treatment, less in ASB.	K C
09	Nickel	Found up to 160 μg/L. Approximately 40% removed in AST treatment, less in ASB.	K C
09	Thallium	Found up to 40 μg/L. Approximately 75% removed in AST treatment, less in ASB.	K C
09	Vanadium	Found up to 140 μg/L. Approximately 70% removed in AST treatment, less in ASB.	K C
09	Zinc	Not used in Ontario mills. Toxic in higher concentrations. Essential for synthesizing certain co-enzymes. Human uses as a nutrient and in creams. Precipitates with phosphates or sulphide. Found up to 1600 μg/L. Approximately 70% removed in AST treatment, less in ASB.	K M C D
12	Mercury	Found up to 3 μg/L.. Average 0.1 μg/L. Probably background concentrations. Not used in Ontario mills. Prior to 1970 mercury compounds were used as slimicides in whitewater systems.	K
15	Sulphide	Very toxic to aerobic life such as fish and crustaceans. Efficiently oxidized to sulphate in aerobic treatment. Precipitates many heavy metals.	K

In Mill Sub-sector column, K= Kraft, M=Sulphite-mechanical, C=Corrugating, D=Deinking/board/fine papers tissue Sector

(Table continues next page)

List of candidate parameters for control *(continued)*

ATG	Variable	Comments	Mill Sub-Sector
	Chlorinated methanes, discussed on page 129		
16	1,1-Dichloroethane	No comments.	D
16	1,1-Dichloroethylene	No comments.	D
16	1,2-Dichloroethane	No comments.	K M D
16	Bromodichloromethane	Formed by the same mechanisms as chloroform when trace amount of bromine is present in the chlorine gas, or by bromide chloride substitution of chloroform if aqueous bromide is present.	K M D
16	Chloromethane	No comments.	M
16	Dibromochloromethane	No comments.	D
16	Dichloromethane (Methylene Chloride)	Believed to be laboratory contamination of samples. Any dichloromethane formed would be purged to the air during aeration in biological treatment plants	K M D
16	Trichloromethane (Chloroform)	Formed in kraft bleach plant chlorination and, principally, in hypochlorination stages. Purged to the air during aeration in biological treatment plants. Hypochlorite bleaching is steadily being eliminated in Ontario mills.	K M C D
16	Trichloroethylene	No comments.	D
16	Tetrachloroethylene	No comments.	D
	Aromatic hydrocarbons, discussed on page 122.		
17	Benzene	These could originate from gasoline and light crude oil sources. Partly degradable in and/or stripped in biological treatment, but is better controlled by minimizing petrochemical spills.	K M D
17	Toluene	Same as for benzene. Often used as a cleaning solvent.	K M D
17	m-Xylene and p-Xylene	Same as for benzene. Often used as a cleaning solvent.	D
17	o-Xylene	Same as for benzene. Often used as a cleaning solvent.	M D
17	Styrene	Same as for benzene. Used as a raw material for the manufacturing of polystyrene foam.	K M

In Mill Sub-sector column, K= Kraft, M=Sulphite-mechanical, C=Corrugating, D=Deinking/board/fine papers/tissue Sector

(Table continues next page)

List of candidate parameters for control *(continued)*

ATG	Variable	Comments	Mill Sub-Sector
	Polyaromatic hydrocarbons, discussed on page 122		
19	Naphthalene	Polyaromatic hydrocarbons (PAH) originate from crude oil or incineration processes. They are widespread in the environment and possibly also in pulp mill effluents, although their source of origin could be elsewhere. These compounds are generally bioaccumulative and highly toxic. Environmental exposure should be minimized. Minimizing their presence specifically in pulp mill effluents may not be the most cost-effective way of reducing environmental exposure. One possible source could be oil based defoamers or other oil-based additives.	K M D
19	2-methyl-naphthalene		D
19	Dibenz(a,h)anthracene		K M
19	Phenanthrene		K
19	Acenaphthylene		K
19	Chrysene		K
19	Fluoranthene		K
19	Benzo(k)fluoranthene		K M
19	Pyrene		K
19	Benzo(g,h,i)perylene		K M
19	Camphene	A normal constituent of wood extractives. Quite persistent in biological treatment.	K M
	Phenolics, discussed on page 129		
20	2,3,5-Trichlorophenol	Could originate from wood preservative formulations. Cannot be made from direct chlorination of lignin precursors. 3 and 5 chloro substituted phenols are more persistent in biological treatment.	K
20	2,4,6-Trichlorophenol	Originate from C-stages. Washed out at the E-stage. Eliminated by O-stages and low chlorine multiples.	K
20	2,4-Dichlorophenol	Originate from C-stages. Washed out at the E-stage. Reduced in biological treatment.	K
20	m-Cresol	Possibly from coal tar dyes.	K M D
20	o-Cresol	Possibly a petrochemical origin. Reduced 40%-75% in biological treatment, but spills control of petrochemicals may be a more effective control measure.	K C
20	p-Cresol		K M D
20	Pentachlorophenol		D
20	Phenol	A common constituent in black liquor as well as in petrochemicals. Phenol is readily degradable and is digested in biological treatment plants.	K M C D

In Mill Sub-sector column, K= Kraft, M=Sulphite-mechanical, C=Corrugating, D=Deinking/board/fine papers/tissue Sector. *(Table continues next page)*

List of candidate parameters for control *(continued)*

ATG	Variable	Comments	Mill Sub-Sector			
	Chlorinated lipophilics, discussed on page 137					
23	1,2,3,4-Tetrachlorobenzene	Chlorobenzenes are mainly used as dye carriers in the textile industry. Other uses include as intermediates in herbicide manufacturing, dielectric fluid, heat transfer medium, degreasing agents, septic tanks, wood preservatives and abrasive formulations (hydraulic oil). Chlorobenzenes resist biological treatment unless especially adapted activated sludge is used, and they tend to accumulate in aquatic biota. Except for a possible minor use as an abrasive agent there should be no obvious source of chlorobenzenes in pulp mill effluents. They are not formed by chlorination in the bleach plant. Therefore, chlorobenzenes are most effectively controlled at their source, i.e. the chemical industry.	K			D
23	1,2,3,5-Tetrachlorobenzene		K			
23	1,2,4,5-Tetrachlorobenzene		K			
23	1,2,3-Trichlorobenzene		K	M		D
23	1,2,4-Trichlorobenzene		K	M		D
23	2,4,5-Trichlorotoluene		K	M		
23	Pentachlorobenzene		K	M		
23	Hexachlorobenzene	Hexachlorobenzene has a number of different applications in organic synthesis. It is much more persistent and toxic than the lower homologues. May associate with bio-sludge.	K			
23	Hexachlorobutadiene	Used as a solvent for rubber, in transformers, in hydraulic oil, and as a degreasing agent. Widely distributed in the environment, bioaccumulating and toxic to aquatic life. Biological treatment plants are normally able to degrade hexachlorobutadiene	K			
23	Hexachlorocyclopentadiene	Used as a flame protection agent, but has other uses such as in the manufacturing of resins. Bioaccumulating and highly acute toxic towards fish, especially larvae. May associate with bio-sludge.	K			D
23	Hexachloroethane	No comments.	K			
23	Octachlorostyrene	No comments.	K			

In Mill Sub-sector column, K= Kraft, M=Sulphite-mechanical, C=Corrugating, D=Deinking/board/fine papers/tissue Sector.

(Table continues next page)

List of candidate parameters for control *(continued)*

ATG	Variable	Comments	Mill Sub-Sector			
	Dioxins and furans, discussed on page 133					
24	2,3,7,8 TCDD	PCDD/PCDF appear to be formed almost entirely in the first C/D-stage. The actual amounts of PCDD/PCDF formed depend on the concentration of molecular chlorine in this stage and the concentration of DBD and DBF precursors in the brown stock. The chlorination factor appears to be the more important of the two.	K			
24	Octachlorodibenzo-p-dioxin		K	M	C	D
24	Octachlorodibenzo-furan		K	M	C	
24	Total H6CDD		K		C	
24	Total H6CDF		K			D
24	Total H7CDD	During biological treatment PCDD/PCDFs are associated with the sludge phase.	K		C	
24	Total H7CDF		K		C	
24	Total PCDD	Dechlorination of highly chlorinated organics takes place more easily under anaerobic conditions i.e. in the sludge.	K			
24	Total PCDF		K			
24	Total TCDD	PCDD/PCDF was also found in Ontario mills that have no bleach plant operation. There is no known control technology for these non-kraft mills.	K			
24	Total TCDF		K		C	D
	Resin and fatty acids, discussed on page 120					
26	Abietic Acid	Resin acids are naturally occurring compounds in wood resins, particularly in pine and spruce. Released during mechanical and kraft pulping. Very toxic to fish and the most frequent reason for a pulp and paper mill effluent sample failing toxicity testing. Substantial amounts in kraft mill effluents indicate soap spills or black liquor carry-over from the evaporators. Reduced by spills control and biological treatment.	K	M	C	D
26	Chlorodehydroabietic Acid		K	M	C	D
26	Dehydroabietic Acid		K	M	C	D
26	Isopimaric Acid		K	M	C	D
26	Levopimaric Acid		K	M	C	D
26	Neoabietic Acid		K	M	C	D
26	Pimaric Acid		K	M	C	D
26	Oleic Acid	This is a fatty acid. However, the discussion on resin acids applies.	K	M	C	D
PP3	Dichlorodehydroabietic Acid	Controlled by either reducing black liquor carry-over to the bleach plant and/or reducing the chlorine multiple at the C-stage. Refer to resin acid discussion. More persistent in biological treatment.	K			

In Mill Sub-sector column, K= Kraft, M=Sulphite-mechanical, C=Corrugating, D=Deinking/board/fine papers/tissue Sector

1.7 Attainable Effluent Characteristics

1.7.1 Conventional pollutants

Technically proven in-plant process modifications to reduce effluent discharges at source in combination with widely used external treatment processes can reduce waste water discharges to the levels shown in Table 2. Table 27 on page 214 presents the maxima recorded in several of the plants that served as the basis for calculation of the data in Table 2.

The effluent from an activated sludge treatment (AST) system can be expected to be better than that from an aerated stabilization basin in most respects. These data do not provide any indication of the solid waste disposal problem that AST creates, nor the extensive land requirements for an ASB, although both factors would be important in assessing the environmental benefits of these two external treatment processes, one or other of which is used in virtually all pulp and paper industry effluent treatments systems worldwide.

Table 2 Attainable loadings for TSS, BOD, P and N with ASB and AST processes

	Aerated stabilization basin				**Activated sludge treatment**			
	LTA	AVG_{95}	AVG_{30}	MAX_{95}	LTA	AVG_{95}	AVG_{30}	MAX_{95}
TSS	2.3	2.25	2.75	3.5	1.05	1.0	1.5	2.0
BOD	1.05	1.0	1.5	2.5	0.55	0.5	0.75	1.25
Total phosphorus	0.04	0.04	0.05	0.075	0.04	0.04	0.05	0.1
Total Kjeldahl Nitrogen	0.45	0.45	0.5	0.9	0.5	0.5	0.6	1.0

Data are shown as kg/tonne product, **calculated as (daily discharge)/(average production rate).**

AVG_{30} (30 days rolling average) AVG_{95} (Annual 95 percentile average) MAX_{95} (Maximum day, 95th percentile)

If a tertiary treatment system using chemically assisted coagulation or granular media filtration, were added to an activated sludge system, then the effluent quality could be further improved. TSS and nutrient discharges could be reduced by 50%, and BOD by 25%. Neither of these tertiary treatment processes could be expected to improve ASB effluent significantly.

1.7.2 Discharges of nutrients

Nutrients (phosphorus and nitrogen) are of increasing concern, particularly in the Great Lakes Basin. Phosphorus is generally considered to be the more important in Ontario.

Phosphorus presents a dilemma to regulators of the Ontario pulp and paper industry. It seems to be generally agreed that most receiving waters in Ontario would benefit from reductions in phosphorus input, while the addition of the biological effluent treatment plants which can reduce BOD and other pollutants so efficiently can result in increased discharges of phosphorus. The alternative technology trains evaluated in this report all incorporate biological treatment, since it is by far the most efficient way of reducing the end-of-pipe discharges of BOD, and acute lethality to fish and *Daphnia magna*. Examination of the environmental trade-off between these latter parameters and nutrient effects can only be undertaken by consideration of receiving waters.

An aerated stabilization basin can operate without addition of nutrients, so would not add any to the receiving waters beyond the quantities naturally present in the untreated effluent. It is generally accepted that an ASB operating without these additional nutrients will be somewhat less efficient than one with nutrient addition. However, the data on performance of the Hinton and Peace River bleached kraft mills, both of which have ASB systems, are quite similar, although Hinton did not add phosphorus during the 1990/early 1991 period, while the Peace River mill did so.

1.7.3 Adsorbable organic halogen (AOX)

Discharges of organochlorines, as measured by the AOX procedure, occur only from mills bleaching pulp with chlorine and chlorine compounds. Discharges from mills in Ontario are generally reported in terms of kg of AOX per tonne bleached pulp manufactured, although 6 of the 9 mills in the kraft sub-sector manufacture other paper products on the same site, and share the same effluent treatment and disposal systems. Discharges in the Ontario mills during the first six months of 1990 ranged from 1 kg/tonne bleached pulp at E.B. Eddy, Espanola, to 7 kg/tonne bleached pulp.

1.7.4 Polychlorinated dioxins and furans from kraft mills

2,3,7,8 TCDD was found in two Ontario mills in the first six months of MISA monitoring. James River, Marathon, had 9 and 13 μg/tonne in two samples, non-detect in the other four samples. Kimberly-Clark at Terrace Bay had 1.8 and 2.5 μg/tonne, with no detectable 2,3,7,8 TCDD in the four other tests in the period. In the USEPA "104 mill" study to determine TCDD/TCDF emissions from the 104 chemical (mostly kraft) pulp mills in the US which use chlorine bleaching, three quarters had detectable TCDD in the effluent. About a quarter of the mills discharged higher quantities of TCDD per tonne pulp than the highest value found at Marathon. It is probable that the non-detectable status of TCDD discharges in most Ontario kraft mills reflects the extensive efforts made by most North American mills since 1988 to reduce dioxin, rather than a geographical difference.

In early 1991 a new bleaching system was commissioned at the Marathon mill which has almost certainly eliminated detectable quantities of TCDD from the mill's effluent. Kimberly-Clark in Terrace Bay is the only other mill where 2,3,7,8-TCDD was found. The rest of the mills had occasional samples containing PCDFs or octachlorodibenzo-p-dioxin (OCDD), the least toxic isomer. As discussed elsewhere in this report, the technology of reducing the PCDD/PCDFs in kraft mill effluent below detection levels is well developed.

1.7.5 Polychlorinated dioxins and furans from non-kraft mills

Mills without molecular chlorine bleaching operations would not be expected to have detectable quantities of PCDD/PCDF in their effluents, except perhaps for the ubiquitous and relatively benign octa-chlorinated homologues. This is the case for Ontario non-kraft mills, i.e. no 2,3,7,8-TCDD has been reported. However, occasionally samples have been reported with contents of PCDD/PCDF. A few of the other mills occasionally show contents of OCDD/OCDF in particular, but again at very low levels as compared to the study of 104 US mills mentioned above. In contrast to the kraft mills, there has been little attention paid by researchers to eliminating these substances from non-kraft effluents. This is perhaps because the amounts found are considered trivial by many scientists, and are certainly insignificant if evaluated under the USEPA toxicity equivalent scale.

The authors had to conclude that there is no proven technology available for control of discharges of dioxins from non-kraft mills.

1.7.6 Equivalent toxicity of dioxins

The "dioxins" frequently referred to in the popular media are a very few members of the polychlorinated dioxin and furan families of chemicals. Some of these are extremely toxic, while others are quite benign, so it would be misleading to simply add the concentrations of each polychlorinated dioxin found in an effluent sample and consider this total to represent the toxicity or environmental significance of the effluent. To overcome this problem, toxicologists have developed weighting factors or Toxicity **EQ**uivalents (TEQ) for each, to express toxicity in terms of the most toxic member of the families, 2,3,7,8 TCDD. Unfortunately, there is not complete agreement between scientists on the exact values for TEQ for all substances.

There are four similar sets of TEQ's relevant to pulp and paper industry effluents, Eadon, NATO, USEPA and Nordic as shown in the table on page 134. The Ministry presently accepts the NATO scale. There is a critical difference between the Eadon and USEPA equivalency factors on the one hand, and the NATO and Nordic on the other. The Octa-chlorinated dioxins and furans are considered to have zero toxic equivalents in the former scales, but to be equivalent to one thousandth of TCDD in the latter. The Octa homologues were the principal dioxins/furans found in the non-kraft mills in the 1990 MISA monitoring program, so it is apparent that the extent of resources to be dedicated to solving this problem (if it is indeed a problem) depends on which TEQ scale is considered the most reliable.

Specific organochlorine compounds

Miscellaneous details on many of the other organochlorines mentioned in Table 1 are provided in the body of the report and the appendices, but do not lend themselves to simple summary.

1.7.7 Metals

Metals cannot be destroyed, only redistributed in the environment. Biological treatment systems inevitably remove some proportion of metals from the effluent stream being treated. Analysis of whether this is environmentally desirable or not is beyond the scope of the present report. Generally, activated sludge systems will remove over half the metals in an effluent stream, concentrating them in the waste sludge. Chemically assisted coagulation will remove some proportion of the metals, also concentrating them in the waste sludge. Aerated stabilization basins have less effect.

1.7.8 Sub-lethal toxicity

Sub-lethal toxicity in biologically treated effluents is largely due to non-biodegradable substances. Effluent control measures which reduce the discharge of organics by recovery and incineration, or by avoiding their generation by modification of the production processes, can therefore be expected to reduce sub-lethal toxicity more effectively than those that rely primarily on biological treatment. The range of technologies available for kraft mills includes some where most of the reduction of discharges of organic substances is by biological treatment, and others where some of the BOD removal is accomplished by increased recovery and incineration of black liquor solids, and/or bleaching residues. Although both these approaches may reduce BOD equally, the reduction in sub-lethal toxicity will generally be less in the processes which rely principally on biological treatment.

The possibilities for recovering and incinerating toxic substances are limited in the non-kraft sub-sectors if currently demonstrated technology only is considered. These mills currently discharge relatively little non-biodegradable material. If the two effluent free mills currently under construction in Western Canada prove to be successful, then elimination of at least 90% of non-biodegradable toxic substances will become technically feasible for mills in the sulphite/mechanical sub-sector.

1.8 Effluent Discharge Control Technologies

1.8.1 Control at source vs external effluent treatment

Control technologies can be divided into those which control discharges at source and external treatment technologies. In this report a distinction has been made between demonstrated technologies that have a record of excellent full scale performance and emerging technologies that are new techniques which appear technically promising on the basis of pilot plant or full scale trials. In general it would be premature to assess the economics of these emerging technologies, since costs cannot yet be predicted with any certainty.

There is a wide range of proven technology to reduce effluent discharges from pulp and paper mills at their sources, instead of treating contaminated effluents. While these in-plant approaches have been used extensively, many proven methods have not yet been fully exploited, and current research will undoubtedly lead to the development of more advanced processes for manufacture without generating pollutants. "Reduction at source" is generally known in the pulp and paper field, as "in-plant control".

The greatest single advantage of in-plant processes for discharge prevention is that much of the technology reduces or eliminates generation and/or release of the persistent substances which the natural ecosystem cannot destroy or assimilate effectively. In contrast, the conventional biological secondary treatment processes are most efficient in removing the substances that the natural ecosystem can usually assimilate and use quite well, and are relatively inefficient in treating the persistent substances.

Some processes for discharge prevention at source are more economically attractive than external treatment, but many of these that are actually profitable are already implemented. Many of the in-plant processes result in higher costs per unit of conventional pollutants (especially BOD) treated than traditional biological treatment. However they may be more cost effective, or the only available technology, in avoiding discharges of the persistent and bioaccumulative substances.

The principal technical advantage of external treatment is that there is no danger of adversely affecting product quality.

1.8.2 Basis for selection of technology

A technology was considered demonstrated if data were available which could be used to predict its reliability and performance. Demonstrated technologies were selected from the range of available technologies using the following criteria:

Utilized in the pulp and paper industry, or in similar applications producing comparable effluents
Practicality of retrofitting into at least some of the existing facilities
Preferably in commercial use for a significant time, generally one year
Design/sizing and costing information was available or could be developed
Bench or pilot-scale technology was considered in some cases of special interest.
(Note that **cost was not a criteria. This will be addressed in the subsequent economic achievability analysis report** to be prepared by the Ministry).

The process of selecting BAT options from the list of demonstrated technologies considered the following features, listed in approximate declining order of significance:

Ability to remove **persistent** contaminants
Non-lethal to trout and *Daphnia magna*
Effective use of recycling, re-use and reduction, and smallest transfer to other media
Reduction of AOX in effluents from bleached kraft mills
Water conservation.

It was assumed that the mill would not modify the production rates or product mix when selecting applicable technology, although this could be a viable option for some mills to comply with whatever regulations are ultimately adopted.

1.8.3 Discharge prevention at source

Many of the pulp and paper manufacturing processes used in Ontario can be modified to reduce effluent discharges at the source. This usually results in a reduced consumption of energy and raw materials and generation of solid wastes, and a reduction in the capacity of any need for external effluent treatment systems that are required. Known by various names including **"Pollution Prevention at Source"**, **"In-plant Control"** and **"Process Modifications"**, these technologies are particularly well developed for the kraft process which is one of the two principal sources of effluent in the Ontario pulp and paper industry.

The technology discussed for the kraft and corrugating sub-sectors incorporates extensive measures for prevention of discharges at source, prior to external effluent treatment. These sub-sectors lend themselves best to such an approach, and much of the successful research and development in the field of effluent discharge prevention at source has been directed toward the kraft sub-sector.

All types of mills can reduce effluent flows to below 50 m^3/tonne product. This will reduce discharges of many pollutants by a small amount. The prime significance is that the minimum concentrations of BOD, TSS and many other contaminants attainable in the proven effluent treatment processes reach a "floor", so that flows must be minimized if minimum effluent discharges of these parameters are to be attained. Design and management of the whitewater system play a major part in controlling effluent flows, and the in-plant modifications mentioned below for specific pulping processes generally result in concurrent flow reductions.

Technology available for control of effluent parameters other than flow is dependent on the manufacturing process used. For kraft mills the best available technology for reduction of effluent discharges at source would be dry debarking, chip screening by thickness, extended cooking in the digester, high-efficiency pulp washing, oxygen delignification, and partial or complete substitution of chlorine by chlorine dioxide in bleaching[12]. For the sulphite/mechanical sub-sector the choice is limited to replacement of the sulphite pulping operation by TMP or purchasing kraft pulp to reinforce the groundwood pulp which is the principal pulp furnish in the newsprint mills where the sulphite process is presently employed.

Technologies for control of effluent discharges by in-plant measures are being developed at an increasing rate by equipment vendors, research organizations and the mills themselves, so no mill is completely up-to-date in their application. Some of these technologies can be readily retro-fitted. Others are routinely installed in new installations but are extremely expensive to retrofit, except perhaps as part of a major mill rebuild[13].

Oxygen delignification

Since the early 1970s, oxygen delignification has been installed in many European mills, as well as a growing number of mills in the US and in Canada. The filtrate from an oxygen delignification stage is invariably recycled to the chemical recovery system,. The installation of an oxygen stage will allow most bleached kraft mills to reduce bleach plant BOD discharges by approximately 50% and colour by 60%. Discharges of organochlorines will be reduced by approximately 35% to 50% and a 50% reduction of the TER will be attained. Oxygen delignification reduces the Kappa number of the pulp by up to approximately 50%, reducing the quantity of chlorine based compounds in the subsequent bleaching stages by up to almost 50%. An oxygen delignification stage is a prerequisite for more recently developed delignification processes (*Lignox* and ozone) which can potentially be used to further reduce the discharge of chlorinated compounds.

Oxygen delignification systems would require investments in the order of $20 million in a typical Ontario mill, but would reduce operating costs significantly. The process has not been widely accepted in Canada, except for Alberta, but is now in use or under construction in many US mills, with an aggregate capacity of 27% of the US total production of bleached kraft pulp. The two most common reasons advanced for not adopting this technology are that product quality would be adversely affected, and that mills would require a new chemical recovery boiler in addition to the above mentioned capital costs. The first problem seems to have been resolved by the many US and overseas companies who are now installing additional oxygen delignification systems after gaining experience in one or more of their mills since 1970. There are several relatively inexpensive solutions to the second problem reviewed in the body of this report.

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[12] *There is some question as to whether 100% substitution of chlorine with chlorine dioxide is environmentally superior to a lower degree of substitution.*

[13] *The recently developed extended cooking technology for kraft pulp is an excellent example.*

AOX discharge control

All five alternative technology trains considered for the kraft sub-sector will substantially reduce discharges of the bioaccumulative components, and four will reduce discharges of AOX below 1 kg/tonne bleached pulp.

The components of AOX removed differ substantially from one technology train to the other. The additional AOX fraction removed by substitution of 100% of the chlorine in bleaching by chlorine dioxide (as compared with 70%) would consist principally of the low-chlorinated organochlorines that have been found to be synthesized naturally in aquatic ecosystems. Technology trains that rely primarily on extending delignification prior to bleaching[14] will be more effective than the others in removing the wood extractives that are responsible for much of the weak chronic toxicity of pulping effluents.

Biological treatment removes in the order of 40% of AOX. In general this will not be the most environmentally significant fraction. Sub-lethal effects on fish have been reported to be substantially reduced where oxygen delignification is installed, as are discharges of the highly chlorinated lipophilic compounds which resist biological treatment.

Elimination of molecular chlorine from kraft pulp bleaching

There are several technical solutions to the problem of manufacturing bleached kraft pulp without molecular chlorine. These are primarily based on replacing the molecular chlorine with chlorine dioxide and, in some cases, by extended delignification of the pulp, and/or replacement of some of the chlorine with oxygen and hydrogen peroxide. Some of the alternatives have been proven to maintain or improve the characteristics of the pulp produced, but require capital investments of up to $45 million for a 500 tonne/day kraft mill. Some incur increases in operating costs of several dollars per tonne pulp, while some capital-intensive modifications can reduce direct operating costs by up to $15/tonne by reducing chemical demand and by recovering energy.

These approaches will eliminate detectable quantities of PCDD/PCDF including 2,3,7,8 TCDD, that originate in the kraft mill bleach plant[15]. These process changes will reduce the discharges of organochlorines, and some of them will also reduce effluent BOD, colour and toxicity.

Chlorine dioxide can simply be substituted for molecular chlorine to bleach pulp. This practice improves effluent and pulp quality, at least up to substitution levels well above the 5% to 35%

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[14] *Extended cooking, oxygen delignification and ozone delignification.*

[15] *Ontario mills have voluntarily eliminated use of precursor bearing defoamers, and the imminent Environment Canada regulations will ensure that this practice continues.*

normally used prior to 1990. For most mills high substitution of chlorine with chlorine dioxide is the simplest, most widely demonstrated and lowest capital cost approach to reducing AOX discharges. However, the operating cost is high, and this approach does not prepare the mill for future installation of ozone delignification or other emerging processes leading toward zero effluent operation. Relative to a mill with neither oxygen delignification nor chlorine dioxide substitution, the latter can reduce organochlorine discharges by up to approximately 80%, if all of the molecular chlorine is replaced, while oxygen delignification would achieve about 40% reduction in the same mill.

In 1990, the highest chlorine use in Ontario was approximately 60 kg/tonne. A softwood mill substituting chlorine dioxide for all chlorine would use approximately 40 kg of chlorine dioxide (containing 21 kg chlorine) per tonne pulp.

Elimination of chlorine compounds from kraft pulp bleaching

Kraft pulp has been bleached in laboratories to market quality without using any molecular chlorine or chlorine compounds in the process. There is no demonstrated industrial-scale technology for complete elimination of chlorine compounds from processes which must be used to bleach kraft pulp to the quality currently required by most customers, although very promising pilot plant work has been carried out by several independent researchers. Technology for eliminating the need for chlorine compounds is developing rapidly.

Although there are not yet any full scale installations manufacturing fully bleached kraft pulp without using chlorine compounds, several mills operate with substantially lower quantities of chlorine compounds than in the past, and much of the technology they use is on a logical path toward the ultimate installation of the emerging chlorine compound free bleaching technologies.

The proceedings of the SPCI pulp bleaching conference in Stockholm in June 1991 included several papers with "chlorine-free bleaching" in their titles, but careful examination revealed that authors were either describing "molecular chlorine free" bleaching, or were discussing laboratory trials only. A review of the proceedings made it clear that several well known research groups are devoting intensive efforts towards developing a practical process for producing market quality pulps without chlorine compounds. Most experts seemed to agree that the **proven technologies of oxygen delignification and extended cooking should be exploited to the maximum prior to use of the relatively expensive and less efficient chlorine compound free bleaching agents.**

Proven parts of probable chlorine compound-free-bleaching processes include extended cooking, oxygen delignification and partial replacement of chlorine compounds with hydrogen peroxide. If used to the maximum extent that they have been proven successful and reliable to date, these process modifications would eliminate approximately 35% of the chlorine dioxide that would remain after the molecular-chlorine-free bleaching processes, discussed on page 34, had been implemented. Laboratory and pilot trials have indicated that the use the technologies listed below can perhaps replace these remaining chlorine compounds, **so that there is reason to expect that it will be technically feasible to manufacture bleached kraft pulp without chlorine compounds within a few years**.

The principal process alternatives which could potentially eliminate chlorine compounds from kraft pulp bleaching in the future are:

The oxygen/ozone process being developed by several companies of which the most advanced at present is under construction by the Union Camp Corporation in Franklin, Virginia.

The Hydrogen Peroxide process; of which the *Lignox* process is best known, being developed by Eka Nobel and under trial at the Munksjo company's Aspa mill in Sweden,

Developments in enzyme bleaching and the use of hydrogen peroxide and/or sodium hydrosulphite seem likely to replace some of the chlorine compounds traditionally used.

The oxygen/ozone bleach plant under construction at Franklin will use an OZED bleach sequence to produce 85 ISO brightness bleached pulp for the mill's own use. Other data indicates that it probably could be modified to attain market quality by using about 10 kg/tonne chlorine dioxide, which would represent a reduction of 75% from the above mentioned molecular-chlorine-free process which depends on 100% substitution. Laboratory trials have indicated that this remaining chlorine dioxide can perhaps be replaced with hydrogen peroxide, sodium hydrosulphite or other chlorine compound free chemicals, but there are no published results from any industrial-pilot scale trials. Such trials seem likely to take place before the end of 1991, but the commercial developers have not been publicizing their plans, presumably for competitive reasons. Ozone delignification will requires significant investments, but will lower operating costs significantly.

Full scale trials on producing fully bleached market quality pulp with the *Lignox* process followed by chlorine dioxide bleaching indicated that slightly over 15 kg of chlorine dioxide per tonne pulp would be required. This represents lower use of chlorine compounds than a conventional bleach plant using oxygen delignification, and is similar to the use of chlorine compounds for a bleach plant preceded by oxygen delignification and state-of-the-art extended cooking, as is used in technology train K5 in Chapter 7 of this report. The published data on the trial indicates an AOX discharge of 0.3 kg/tonne pulp. The mill concerned (Aspa, Sweden) practices neither extended cooking nor biological treatment. If the effluent were treated biologically, then the final AOX discharge would be about 0.2 kg/tonne pulp. The promoters of the *Lignox* process consider that they can improve the performance after further research and development work. At present the maximum brightness obtained without chlorine compounds is approximately 75 ISO. The authors consider the *Lignox* process to be a "low-capital/high-operating-cost" approach to improving effluent quality.

It is technically feasible to produce semi-bleached kraft pulp without the use of chlorine compounds, but the only mill doing so commercially (Aspa) is reported to be unable to sell all of the chlorine-compound-free pulp it can manufacture. The vendors of the *Lignox* technology have advised that they expect it to be some time before they will offer the process commercially in Canada.

White water management

Environmental legislation and rising energy costs have led to significant reductions in process water consumption during the last 40 years in pulp and paper mills. This has been less evident in Canada partly due to regulatory requirements discouraging water conservation programs, because toxicity tests which have been the cornerstone of much of the regulatory activities, are based on concentration rather than toxicity emission rates (Refer to the Glossary definition of TEF and TER). It is standard practice to recycle water within a mill. The degree of recycling, however, varies widely.

Sodium based sulphite mills

This sub-sector includes the two Ontario corrugating medium mills as well as the high yield sulphite pulping operations at the newsprint mills.

The options for discharge prevention at source for the corrugating board mills include changing to a soda pulping process and then installing a fluidized bed furnace based recovery system in which black liquor is burned and soda is recovered. Alternatively corrugating medium can be made from 100% secondary fibres in closed cycle mills, thus eliminating process effluent.

Fluidized bed incineration of the waste liquor also is possible for sodium based sulphite mills that use the pulp for newsprint strength improvements, but this would create the problem of selling the recovered sodium sulphate. Due to difficulties in separating the waste liquor from the pulp, a liquor incineration system mill would be a large energy consumer, which perhaps explains the lack of practical applications. Despite extensive research and a number of mill-scale trials over the past 25 years, the authors consider that there is still no sulphite waste liquor recovery system that merits serious consideration for the relatively small, high-pulping-yield mills in Ontario.

Other possibilities are to change to a magnesium based process, to substitute the sulphite pulp with semi-bleached market kraft pulp, install a deinking operation or, most probably, follow the general trend of replacing the groundwood operation with TMP which does not need sulphite pulp for strength improvements.

1.8.4 External treatment technologies

External treatment is utilized as a supplement or an alternative to discharge control at source. It may involve a range of physical-chemical and biological measures. Primary treatment involves removal of suspended solids, normally in a gravity clarifier. All Ontario mills apply this technique. Secondary treatment removes soluble organic materials, normally by biological treatment which primarily removes BOD, and acute toxicity. Seven Ontario mills apply secondary treatment, one of which is anaerobic only. Tertiary treatment can involve different physical-chemical techniques, e.g. granular filtration or chemically aided coagulation to further reduce TSS, phosphorus and others.

Most external effluent treatment processes rely upon, at least to some extent, concentrating the pollutants into a side stream, normally a sludge. Many require addition of chemicals, which may result in additional discharges to the receiving waters. Selection of regulations to control effluent discharge rates must always be a compromise between various aspects, since **there is no single process that is environmentally best, even if cost is ignored.**

Activated sludge treatment (AST)

Activated sludge treatment (AST) is a widely used biological process normally applied to primary treated effluents, and used in many industrial and municipal effluent treatment plants. The principle is to create the conditions for a high concentration of microorganisms to grow on the soluble materials in the effluent. The microorganisms are later separated from the treated effluent as a sludge and recycled in the process. Excess sludge is concentrated and then incinerated or landfilled. AST can achieve lower BOD and TSS discharges than aerated stabilization basins, but generates significant quantities of waste sludge which require chemical additions and are difficult to dispose of in an environmentally satisfactory manner. Biodegradable organics will be largely destroyed or mineralized. The non-biodegradable substances and the heavy metals removed from the waste water are stored in the waste sludge. Energy and chemical requirement for sludge handling makes this process more expensive per unit weight of BOD removed than an ASB system.

Aerated stabilization basin (ASB)

Aerated stabilization basin (ASB) treatment is a biological process widely applied to primary treated effluents. The principle is based on the growth of low concentrations of microorganisms on the soluble materials in the effluent without the sludge recycle that is characteristic of the above mentioned activated sludge process. When the microorganisms die, the sludge is used as food by other microorganisms, and thus the BOD is digested. The successful operation of an ASB system involves the control of the non-digestible sludge so that minimal quantities of TSS and BOD are discharged in the final effluent without the dredging of accumulated sludge being necessary. The energy requirements for an ASB system are lower than for an AST system and **generation of waste sludge is avoided**. However, concentrations of BOD and TSS in aerated stabilization basin effluents are about double those for AST systems.

Acute lethality

There has long been controversy about the ability of the above mentioned AST and ASB technologies to treat pulp mill effluents sufficiently well to pass the standard acute lethality tests for trout and *Daphnia magna*. The performance of the effluent treatment systems using these processes, and described in Appendix C, has been excellent in this regard. All the Canadian mills mentioned in Appendix C have consistently passed their routine tests of acute lethality for some time, demonstrating that it is possible to design and operate pulp and paper mills without discharging acutely lethal effluent. There is little or no information available on the non-Canadian mills in this regard.

Anaerobic treatment

Instead of using one of the above mentioned, aerobic, secondary treatment systems, several mills in North America, including the MacMillan Bloedel mill in Sturgeon Falls, Ontario, have installed anaerobic treatment systems. These rely upon different biological processes from the AST and ASB, and operate in closed vessels without the addition of oxygen. Biomass forms, as in the aerobic systems, and the reaction is characterized by much slower growth, and very little generation of waste sludge. A significant portion of the organic wastes are converted to methane, which is used as a fuel gas in some cases. Anaerobic processes are of interest because of the more attractive energy balance and absence of sludge generation relative to a conventional AST system. Anaerobic processes are widely used in the food industry, but little in the pulp and paper industry. Long start-up times after accidental failure, and difficulties in maintaining reliable operation have been obstacles to acceptance.

Anaerobic treatment is of little interest for treating waste waters with BOD concentrations under about 1000 mg/L. It can lower concentrations of organic substances and BOD in effluent substantially, but has little effect on toxicity. Anaerobic systems must be followed by aerobic systems to achieve the low BOD and toxicity required by most modern regulations.

The authors of this report consider anaerobic treatment processes as offering an opportunity of reducing the cost of effluent treatment in suitable conditions, rather than as effluent treatment in themselves. Anaerobic processes have therefore not been included in any of the alternative technology trains.

Tertiary treatment

Tertiary treatment is, by definition in the field of waste water treatment, any process installed to enhance the quality of the effluent leaving the secondary treatment system. The two technologies potentially applicable in the pulp and paper industry are chemically assisted coagulation and granular filtration.

Chemically assisted coagulation

Chemically assisted coagulation concentrates a proportion of the contaminants in a stream of settleable solids that can be withdrawn from a tertiary clarifier and concentrated for landfill. Removal of heavy metals can be quite efficient, if initial concentrations are high.

The **quantity of waste sludge can be significant**, up to about 30 time the weight of the suspended solids removed from the effluent, or 200 times the quantity of phosphorus removed. Incineration is generally impractical.

Granular filtration

Granular filtration can be used to remove suspended solids, BOD and phosphorus from effluents to a similar extent to chemically assisted coagulation, but is generally less effective in removing heavy metals. There is normally no sludge production, since the filter backwash can be recycled to the secondary treatment system.

Either of these two types of tertiary treatment typically can reduce effluent **BOD from a well operated activated sludge treatment system by in the order of 33%, and will reduce TSS and phosphorus discharges by about 50%.** The attainable reductions in heavy metals are site specific.

Tertiary treatment using these processes downstream of an aerated stabilization basin is unlikely to be effective.

Control of phosphorus discharges

Phosphorus is a limiting nutrient for microbiological growth in the biological treatment of pulp and paper mill effluent. An accurate assessment of the influent BOD load is necessary if phosphorus control is to be satisfactory. With modern pulp and paper industry process control instrumentation it is often possible to predict influent BOD, or alternatively, instruments are becoming available to monitor oxygen demand sufficiently well for use in the control of nutrient addition. Long retention ASB systems often operate without addition of phosphorus. The need for adding phosphorus to an AST can be limited by using established biological phosphorus control techniques to minimize losses of phosphorus with the final effluent.

1.9 Alternative Technology Trains

Capital and operating costs have been estimated for the implementation of a range of effluent control technologies, all of which can be considered as BAT in at least one respect, for each mill in Ontario. In all cases the **costs are based on the mills as they existed in April 1991, with no attempt at estimating the (widely varying) extent of prior investments in effluent control.** Several alternative "technology trains" or groups of effluent control technologies involving both in-plant measures to reduce discharges at source and external treatment were selected for each sub-sector of the industry. The implications of applying these to each mill were examined. The capital and operating costs were estimated and the consequent effluent characteristics predicted.

These technology trains were selected to provide logical, technically sound systems to reduce effluent discharges. They do not represent the only way of attaining the effluent quality discussed in this report, nor do they represent the only technically sound way of combining the wide variety of effluent discharge control technologies available.

The authors carried out a detailed site-by-site analysis to calculate the costs, since this is superior to the more widely used approach of relying on costs calculated on the basis of loads for generic effluent treatment processes. This latter approach was used successfully in the USEPA's well known development documents for effluent guidelines in the 1970s and 1980s. However, they were generally dealing with mills at a fairly limited and uniform level of installation of environmental protection measures, and at a time when technology for effluent control at source was much simpler than is available for Ontario mills to-day. The diversity of manufacturing processes and effluent control measures already implemented in Ontario mills created significant difficulties in estimating costs, and will present obstacles to effective analysis of economic feasibility of the measures involved.

The alternative technology trains are generally selected in order of improving effluent quality. All are based on demonstrated technology, unless otherwise noted.

Each train is an independent group of effluent control technologies, and **in most cases it is neither intended nor economically reasonable for a mill to install first one train then another at a later date.**

In all cases costs represent capital and operating expenses that mills would incur to install the technologies concerned, starting from a baseline in April 1991. All systems that were operational at that time are considered to have zero capital and operating cost. Any effluent discharge control systems that were in progress were assumed to exist, provided that the mill had made a physical commitment to their installation.[16] Although the latter expenditures were generally incurred to comply with the requirements of the Ministry of the Environment, they were NOT incurred as a result of the currently proposed MISA regulations.

The annualized cost of installing, operating and maintaining the equipment for the various technology trains was calculated as:

$$\text{Annualized cost} = (\text{Capital cost}) \times 0.18 + (\text{O\&M cost})$$

This equation corresponds to that used by the Ministry's Fiscal Planning and Economics Analysis Branch, but does not consider the tax implications. It is presented as a practical way of comparing costs of various alternatives, and is not recommended as a substitute for a more complete economic analysis.

1.9.1 Kraft sub-sector

All the alternative technology trains for the kraft sub-sector include extensive in-plant measures for reduction of effluents at source, and biological treatment. The first four use ASB, and the fifth AST to attain the lowest technically feasible BOD and TSS discharges. In two kraft mills, Domtar at Cornwall and CPFP at Thunder Bay AST is used for all trains, due to space limitations. All trains include substantial reduction in effluent flows, which contributes to overall performance of the biological treatment systems, whether existing or yet to be constructed.

The simplest of the five alternative technology trains is aimed primarily at eliminating detectable quantities of TCDD and TCDF, and lowering AOX, in addition to the reductions in BOD, acute toxicity and TSS attained by the above mentioned biological treatment. The second alternative, simply carries this to the logical limit by eliminating molecular chlorine. The third train introduces oxygen delignification and will be more effective in reducing sub-lethal toxicity that the previous ones. The fourth train achieves similar objectives to the third, but uses extended cooking. This reduces total chemical usage, and has some major pulp quality benefits, but requires major modernization of the mills, so the capital costs are high, as is apparent in Figure 1 on page 42. The fifth train is essentially a combination of trains 3 and 4. It is very similar to the design of the most environmentally advanced greenfield mills in the world. **Trains 3, 4 and 5 are logical precursors**

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[16] *Physical commitment implies commencement of construction. Installations that had been announced, purchased or otherwise committed were NOT considered as being physically committed for the purposed of this report.*

for the emerging processes for further reduction and eventual elimination of chlorine compounds including *Lignox* and the various ozone based technologies discussed in Chapter 6.

Details of the capital and operating costs for implementation of each alternative technology train are shown in Chapter 3, along with the expected discharges of the major pollutants.

The capital costs depend on mill size, site conditions, and most importantly the extent of previously installed effluent control measures.

In many cases, the in-plant measures to reduce the formation of pollutants reduce the operating costs by reducing chemical demand. In some of those, the savings are sufficient to outweigh the maintenance costs of the new equipment, as indicated by the total operating and maintenance costs in Figure 2 on page 43.

The costs per unit pollutant removed vary widely according to the extent of removal, and the base level of discharges. For mills which had low effluent discharges in 1990, the unit cost of attaining further reduction is very high.

The capital costs estimated for the application of the five alternative technology trains are summarized below.

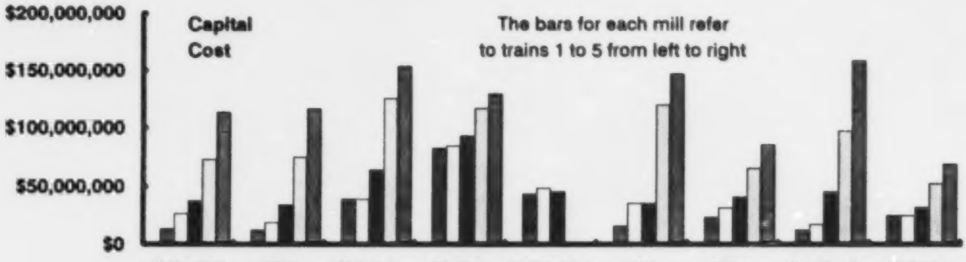

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Figure 1 Capital costs for technology trains for kraft sub-sector

The estimated operating costs for each of the technology trains is presented below. In some cases, the savings in energy, chemicals and labour are sufficient to offset the direct operating costs.

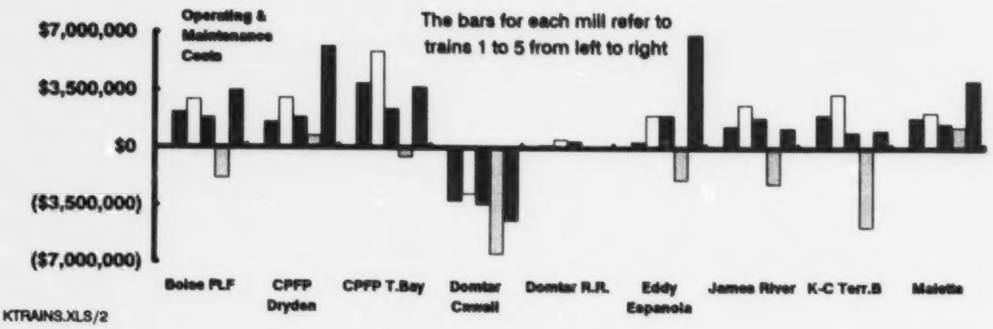

Figure 2 Operating and maintenance costs for technology trains for kraft sub-sector

Other effluent parameters

All the kraft technology trains would discharge approximately equal quantities of nutrients, but trains 3, 4 and 5 would be more effective than trains 1 and 2 in reducing the discharges of sub-lethal toxicity and most of the persistent, non-biodegradable pollutants. The differing COD discharges provide an overall indication of this, since the COD of an effluent that has been subjected to efficient biological treatment is essentially a measure of total non-biodegradable organics. Relative to a kraft mill without biological treatment, trains 1 and 2 will reduce COD by 30%, train 3 by 45%, trains 4 and 5 by 50%.

1.9.2 Sulphite/mechanical sub-sector

The range of technology available for this sub-sector is much narrower than for the kraft sub-sector discussed above. Only three proven technology trains were developed, all of which involve some internal measures to reduce effluents, but rely principally on external treatment. The costs of the potential installations, and current industry trends, suggest that the mills in this sub-sector are more likely to undertake major modernizations which will reduce effluent BOD than to install treatment systems for the existing effluents. The costs of such modernizations could not be justified simply to comply with environmental regulations, but would include considerations such as future product quality requirements, availability of wood, the customer demand for recycled paper in newsprint, and the extensive labour savings realized when a traditional groundwood/sulphite newsprint mill is replaced by TMP. However, analysis of complete modernization of the mills was not within the scope of this project.

The capital costs for implementation of each alternative technology train are shown in Figure 3 below.

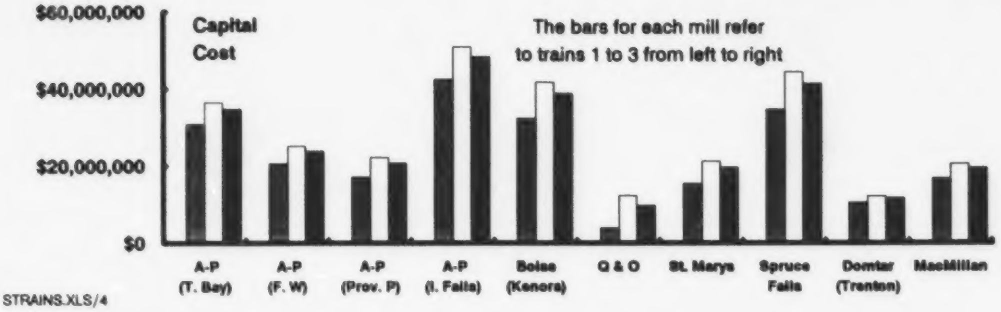

Figure 3 Capital costs for technology trains for sulphite/mechanical and corrugating sub-sectors

The capital costs depend on mill size, site conditions, and most importantly the extent of previously installed effluent control measures.

The operating costs estimated for the application of the three alternative technology trains are as follows:

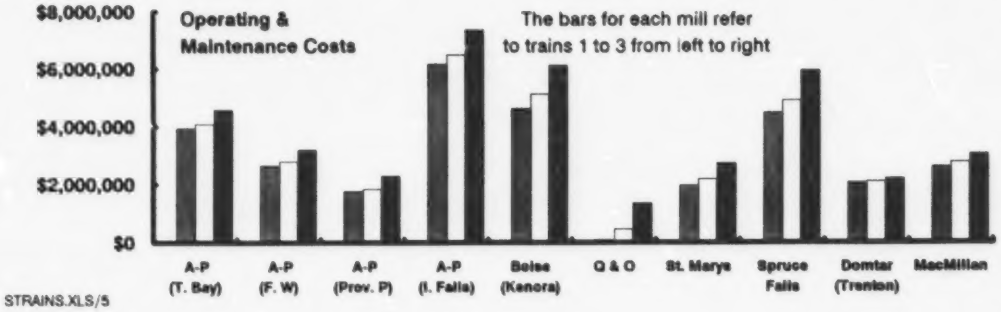

Figure 4 O & M costs for technology trains for sulphite/mechanical and corrugating sub-sectors

1.9.3 Corrugating sub-sector

The additional capital and operating costs for implementation of each alternative technology train are shown in the figures in the sulphite/mechanical sub-sector, discussed above.

1.9.4 Deinking/board/fine papers/tissue sub-sector

The capital and operating costs estimated for the application of the four alternative technology trains are as follows:

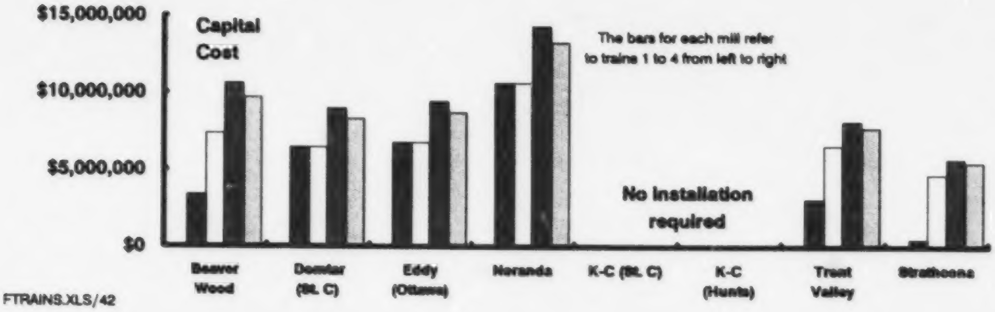

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Figure 5 Capital costs for technology trains for deinking/board/fine papers/tissue sub-sector

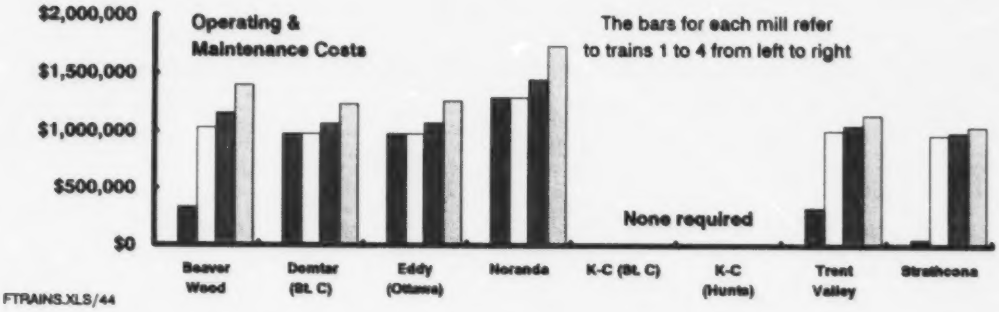

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Figure 6 O & M costs for technology trains for deinking/board/fine papers/tissue sub-sector

1.10 Economic Achievability

Analysis of the economic achievability of the effluent control technologies will be carried out independently by the Ministry of the Environment.

(Notes)

2 INTRODUCTION

SUMMARY This report defines the Best Available Technology (BAT) for pulp and paper mill effluents under Ontario conditions. It does not consider economic achievability (BATEA). Modifications of product line have not been considered as BAT.

Data in this report are presented in **Systeme International, (SI)** units, unless otherwise stated. The word "tonne" refers to the "metric" tonne = 1000 kg = 2205 lbs.

2.1 Background

Over the past few years, the Municipal/Industrial Strategy for Abatement (MISA) in Ontario has been working towards a substantial reduction of toxic contaminant discharges to the Province's waterways, with the ultimate goal of the virtual elimination of persistent contaminants. The program is split into a series of similar but independent sub-programs for each of the major industrial sectors in Ontario. This report addresses all of the pulp and paper sector, except those mills (mostly small) that discharge effluents only to municipal sewers.

An extensive effluent monitoring program was conducted in 1990, and promulgation of new Effluent Limits Regulations is scheduled for 1992.

The Ministry's policy is to base effluent control requirements on the Best Available Technology (BAT)[17] which is economically achievable (BATEA).

N. McCubbin Consultants Inc. were retained by the Ministry to prepare this report after responding to requests for proposal Number 900605 for kraft mills, and Number 900606 for non-kraft mills of December 1990. In view of the extensive technical similarities and geographical overlap between the kraft and non-kraft sub-sectors[18], and the Ministry's interest in minimizing costs, this single combined report has been prepared.

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[17] *Refer to Ontario's definition of BAT discussed on page 55.*

[18] *Note that six of the nine kraft mills have extensive non-kraft manufacturing on-site.*

2.2 Objectives

The objectives of this report are to:

Develop an inventory of the best technology available worldwide for the control of effluents discharged from Ontario's pulp and paper mills.

Develop an inventory of the current effluent discharge control technologies of each of the 27 direct discharge mills in Ontario.

Evaluate several alternative technology trains which could be applied to Ontario mills in each of the four sub-sectors of the industry, including an assessment of technical feasibility, consequent effluent quality and costs (both capital and annual operating).

Provide a basis for economic assessment of the possibility of implementing the identified BAT in Ontario's pulp and paper industry.

The full terms of reference are appended.

2.3 Sources of Ontario Mill Data

Data on Ontario mill effluents used in the calculations of costs and in formulating conclusions in this report were taken from the report on the first six months of the MISA monitoring program (MISA 1991). In some cases, where insufficient data were available, MOE data from previous years were used. This applies mostly to acute lethality to trout. The authors also reviewed as much of the data for organochlorines as was available for the latter part of 1990, since it was expected that some reductions may have occurred due to company programs to reduce AOX and dioxin discharges.

All cost estimates are based on mills as they existed in April, 1991. Where mills had projects under way on that date that would improve effluent quality, the authors assumed that they would be completed. The costs of these projects were not considered as part of the cost of implementing further measures to comply with potential BAT based regulatory requirements under MISA. Where construction had not clearly commenced, such projects were considered as tentative.

Operating data for the mills were collected by contact with the mill staff directly. Where responses were not received, some operating data were estimated from information in MOE files and published documents. In all cases, mills were advised of such assumptions and were invited to correct any errors.

2.4 Pulp and Paper Sector Profile

There are 27 mills in the pulp and paper sector which discharge treated industrial effluents directly to watercourses[19]. The extent of in-plant measures for reduction of effluent discharges at source, and the degree of effluent treatment varies very widely from mill to mill. The mills are mostly at least 25 years old. The Kimberly-Clark mill at Huntsville is the only mill built since 1965 when paper industry effluent discharges first became a serious concern in Ontario. Some companies have invested considerable sums in modernizing their facilities, so that some can be considered as modern with respect to effluent discharge control. Others are quite outdated. The only mill which can be considered to discharge extremely low quantities of effluents by worldwide standards is the Kimberly-Clark mill at Huntsville.

All mills have primary effluent treatment, and seven have secondary treatment.

Effluent discharges range from slightly under 1000 to 173,000 m^3/day, carrying from 3 to 49,000 kg/day BOD.

Several mills are in the process of implementing effluent discharge control measures[20], including some that have come into service since the 1990 MISA effluent monitoring program was completed[21]. Eight of the nine bleached kraft mills have undertaken measures in the past few years to reduce discharges of organochlorines (AOX), including the PCDD/PCDF group ("dioxins" in colloquial terms) and one mill has a large secondary treatment system under construction. James River at Marathon and Kimberly-Clark at Terrace Bay were the only mills where 2,3,7,8-TCDD was detected during the first six months of the 1990 MISA effluent monitoring program. The Marathon bleach plant has since been modified to operate without molecular chlorine, which is one of a number of ways to lower emissions below detectable levels.

The locations of all mills are shown on the map following, and details of products, etc. in Appendix A.

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[19] *Several other mills discharge their effluents to municipal sewers. These are not discussed in this report.*

[20] *For example, an oxygen activated sludge effluent treatment system is under construction at the CPFP mill at Thunder Bay.*

[21] *Including capability to bleach kraft pulp without the use of molecular chlorine at James River, Marathon and Boise Cascade in Fort Frances.*

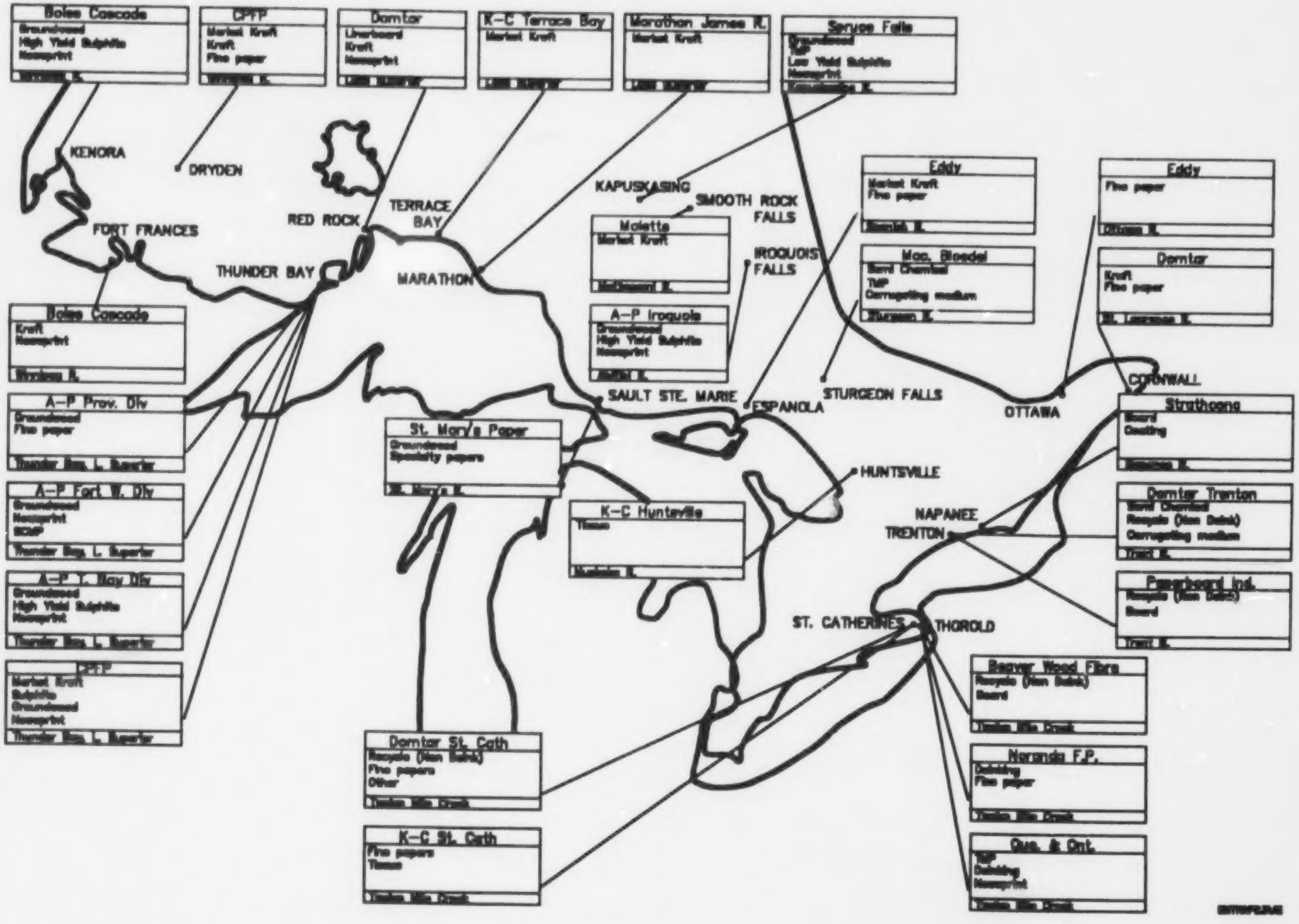
Boise Cascade
Groundwood
High Yield Sulphite
Newsprint
Winnipeg R.
CPFP
Market Kraft
Kraft
Fine paper
Wabigoon R.
Domtar
Linerboard
Kraft
Newsprint
Lake Superior
K-C Terrace Bay
Market Kraft
Lake Superior
Marathon James R.
Market Kraft
Lake Superior
Spruce Falls
Groundwood
TMP
Low Yield Sulphite
Newsprint
Kapuskasing R.
KENORA
DRYDEN
FORT FRANCES
RED ROCK
TERRACE BAY
THUNDER BAY
MARATHON
KAPUSKASING
SMOOTH ROCK FALLS
IROQUOIS FALLS
SAULT STE. MARIE
ESPANOLA
STURGEON FALLS
OTTAWA
CORNWALL
HUNTSVILLE
NAPANEE
TRENTON
ST. CATHERINES
THOROLD
Molette
Market Kraft
Mattagami R.
A-P Iroquois
Groundwood
High Yield Sulphite
Newsprint
Abitibi R.
Eddy
Market Kraft
Fine paper
Spanish R.
Mac. Bloedel
Semi Chemical
TMP
Corrugating medium
Sturgeon R.
Eddy
Fine paper
Ottawa R.
Domtar
Kraft
Fine paper
St. Lawrence R.
Boise Cascade
Kraft
Newsprint
Winnipeg R.
A-P Prov. Div
Groundwood
Fine paper
Thunder Bay, L. Superior
A-P Fort W. Div
Groundwood
Newsprint
BCMP
Thunder Bay, L. Superior
A-P T. Bay Div
Groundwood
High Yield Sulphite
Newsprint
Thunder Bay, L. Superior
CPFP
Market Kraft
Sulphite
Groundwood
Newsprint
Thunder Bay, L. Superior
St. Mary's Paper
Groundwood
Specialty papers
St. Mary's R.
K-C Huntsville
Tissue
Muskoka R.
Domtar St. Cath
Recycle (Non Deink)
Fine papers
Other
Twelve Mile Creek
K-C St. Cath
Fine papers
Tissue
Twelve Mile Creek
Strathcona
Board
Coating
Napanee R.
Domtar Trenton
Semi Chemical
Recycle (Non Deink)
Corrugating medium
Trent R.
Paperboard Ind.
Recycle (Non Deink)
Board
Trent R.
Beaver Wood Fibre
Recycle (Non Deink)
Board
Twelve Mile Creek
Noranda F.P.
Deinking
Fine paper
Twelve Mile Creek
Que. & Ont.
TMP
Deinking
Newsprint
Twelve Mile Creek

Figure 7 Location of direct discharge pulp and paper mills in Ontario

2.5 Mills Included in Scope

The mills included in the scope of this study are listed in Table 3.

Table 3 Mills within scope of report

Company	Town	Abbreviation
Kraft sub-sector		
Boise Cascade Canada Ltd.	Fort Frances	Boise (Ft. F)
Canadian Pacific Forest Products Ltd.	Dryden	CPFP (Dryden)
Canadian Pacific Forest Products Ltd.	Thunder Bay	CPFP (T. Bay)
Domtar Inc., Fine Papers Div.	Cornwall	Domtar (Cnwall)
Domtar Inc., Containerboard Division	Red Rock	Domtar (R.R.)
E.B. Eddy Forest Products Ltd.	Espanola	Eddy (Espanola)
James River-Marathon Ltd.	Marathon	James River
Kimberly-Clark Canada Inc.	Terrace Bay	K-C (Terr. B)
Malette Kraft Pulp and Paper Co.	Smooth Rock Falls	Malette
Sulphite-mechanical sub-sector		
Abitibi-Price Inc., Thunder Bay Div.	Thunder Bay	A-P (T. Bay)
Abitibi-Price Inc., Fort William Div.	Thunder Bay	A-P (F. W)
Abitibi-Price Inc., Provincial Papers Div.	Thunder Bay	A-P (Prov. P)
Abitibi-Price Inc., Iroquois Falls Div.	Iroquois Falls	A-P (I. Falls)
Boise Cascade Canada Ltd.	Kenora	Boise (Kenora)
Quebec and Ontario Paper Company Ltd.	Thorold	Q & O
St. Marys Paper Inc.	Sault Ste. Marie	St. Marys
Spruce Falls Power and Paper Company Ltd.	Kapuskasing	Spruce Falls
Corrugating sub-sector		
Domtar Inc., Containerboard Division	Trenton	Domtar (Tren)
MacMillan Bloedel Ltd.	Sturgeon Falls	MacMillan
Deinking/board/fine papers/tissue sub-sector		
Beaver Wood Fibre Company Ltd.	Thorold	Beaver Wood
Domtar Inc., Fine Papers Div.	St. Catharines	Domtar (St. C)
E. B. Eddy Forest Products Ltd.	Ottawa	Eddy (Ottawa)
Noranda Forest Inc., Recycled Papers	Thorold	Noranda
Kimberly-Clark Canada Inc.	St. Catharines	K-C (St. C)
Kimberly-Clark Canada Inc.	Huntsville	K-C (Hunts)
Trent Valley Division, Paperboard Industries Corporation*	Trenton	Trent Valley
Strathcona Paper Company	Napanee	Strathcona

The abbreviated names are used in the MISA Monitoring report (MISA 1991) and in the graphs in this report where appropriate. The names of the two Domtar Containerboard Division mills were changed to "Domtar Packaging Division" early in 1991, but this report has retained the 1990 names to correspond with prior MISA reports. Form used in MISA 6 month report.

2.6 Scientific Versus Industrial Practices

In carrying out a study of this nature, it is necessary to adopt an approach that is intermediate between the scientist's rigorous approach to verification of all facts, and the businessman's practice of making decisions in a limited time frame without awaiting all the information that he may like to have.

2.6.1 Science

Science is based on the fundamental concept of reproducibility. An experiment conducted, e.g. in Scandinavia, must give the same result if conducted in Ontario in order to be considered to be scientific. Over the past two centuries the mathematical science of statistics has been developed to assess the validity of scientific results in terms of whether or not they are "significant". Stringent rules apply to analytical results if they are to be validated as "scientific" (including Quality Assurance, Quality Control, intercalibration exercises, handling of outliers etc).

Most of our modern understanding of the world is based on reproducible scientific results. The scientists establish a hypothesis and conduct an experiment that should contradict the hypothesis. If a well-designed and conducted experiment fails to contradict the hypothesis, the hypothesis is judged to be "true". In modern science one can seriously talk about the half-life of a "true" theory. The average half-life may be in the order of 50 years or less, before someone conducts an experiment that will contradict the theory. Experience has shown that in new fields of study, the "half-life" of true theories is often shorter. The effluent control technologies discussed in this report range from processes over 100 years old to very recently developed ideas such as for AOX, so some will probably become obsolete within a few years.

2.6.2 Technology

Sometimes one is led to believe that technology is based solely on scientific evidence. However, if this were true, modern civilization would not look the way it does. It is closer to the truth, to say that most technology was invented by accident by persons with highly developed imaginations and intuitions, usually with some technical training and access to experimental or industrial equipment to conduct trials. Only then, when the technology is invented, can scientists develop the theories that make us believe they understand why a given technology is working.

The development of modern pulp and paper technology is a very good example of a technology that was developed on the basis of empirical rather than scientific evidence. Therefore, when judging the concept of BAT, one has to give credit to evidence that is based on intuition and less-than-scientific analysis of full-scale operations, pilot plants and experimental data, as well as to the scientific basis.

Although a pulp mill's compliance with a wastewater permit stating specific limits should, in principle, be demonstrated through reproducible sampling and analyses, the available data are rarely sufficiently numerous and of a quality that would pass a scientific analysis. This would be much too time-consuming and very often a waste of money. The statistical uncertainty of any demonstrated result should not be forgotten, and it must be combined with the professional judgement or common sense of skilled persons.

2.6.3 Scientific and technical literature

Extensive literature searches were conducted to minimize the risk of any useful effluent control technologies being overlooked. Most of the searches used the Institute of Paper Science and Technology's PAPERCHEM database which is readily searched by computer. It includes over 450,000 citations from approximately 1000 periodicals in over 20 languages, as well as proceedings from major conferences related to the pulp and paper industry. Enviroline, containing about 350,000 citations was also consulted, but no references were found which were not also in PAPERCHEM.

The authors reviewed all literature referred to in this report critically. Only references which the authors collectively have confidence in were used as the basis for decisions. The principal criteria for evaluating the credibility of the data from the literature and other sources was the extent of independent confirmation, correlation with our own experience, as well as the degree of independence of the source author and his reputation.

2.6.4 Decision-making practices in the pulp and paper industry

Good management in the pulp and paper industry can not rely solely on scientifically "significant" results, whether for decisions concerning investments in production facilities, or for selection of appropriate environmental protection systems. Technology and demands from society move much too fast to do so. One example is the rapid and widespread installation of chlorine dioxide generators in kraft mills across North America, at a capital cost in the order of one billion dollars.

Many of the results on which the conclusions of this report are based are not "statistically significant". In such cases, the conclusions must sometimes be based on "best professional judgement", given the present state-of-the-art. The possibility always exists that the conclusions may be contradicted by new evidence in the future, but they reflect the considered opinion, at the time of writing, of six internationally experienced consultants with a broad range of expertise.

2.7 Approach to Selection of Relevant Technology

The Ministry's definition of "Best Available Technology" is of necessity flexible, since "best" is a moving target. Available technologies were first identified; those which were not demonstrated were set aside; and the best were selected as discussed below.

2.7.1 Available technologies

An initial list of available technologies was developed from the author's experience, a list published in the USEPA development document, extensive searching of the scientific literature, as well as suggestions from Ministry staff, Greenpeace and individuals within the pulp and paper industry.

Several separate selections were made for each sub-sector of the pulp and paper industry with some range in effluent quality. In some cases several similar technologies could be used to achieve essentially identical results. Therefore, it was found to be necessary to restrict detailed evaluation and reporting to one of such alternatives, in view of the time and budget constraints involved in the project[22].

The following were considered as potentially viable approaches to improving effluent quality:

Changes in production processes
Discharge prevention at source
Effluent treatment technologies
Best management practices

Applications of the above approaches, either individually or in combination, used to control the quality of effluent anywhere in the world were considered to be available technology. Experience in comparable industrial sectors that produce untreated process effluents with characteristics similar to those produced by the pulp and paper industry was also considered.

Changes in production processes and discharge prevention at source are techniques used to improve effluent quality by reducing or eliminating the formation of pollutants. Examples include installation of oxygen delignification systems to reduce the use of molecular chlorine for pulp bleaching, or recycling of lightly contaminated water to replace fresh water.

Effluent treatment processes are considered to be those technologies which are used to eliminate or reduce the total loading of conventional and toxic contaminant substances from process effluent streams. This is often known as "external treatment" or "ex-plant treatment".

Best management practices are those facilities or procedures used to:

Manage site runoff and drainage from outdoor process and non-process areas resulting from storm water or thaw events
Control once through cooling water
Minimize variations in performance of effluent treatment systems
Manage sludge and waste disposal
Minimize the impact of spills.

2.7.2 Demonstrated technologies

A technology was considered to be a **demonstrated technology** if data were available which can be used to predict, with a reasonable degree of confidence, its reliability and performance. These relate to effluent quality improvements at any plant in the pulp and paper sector, given the expected variability between plants.

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[22] *This applies mostly to the kraft sector, where there is a very wide variety of technologies available for AOX, BOD and toxicity control. The authors frequently evaluate specific options for industrial clients, and used this experience to select the most effective technologies for more detailed analysis.*

Demonstrated technologies were selected by the authors from the range of available technologies on the basis of the following criteria:

Utilized in the pulp and paper sector or in a similar industrial sector or sub-sector that produces effluents with similar characteristics
Practicality of retrofit in at least some of the existing facilities
Preferably in commercial use for a significant time (generally one year)
Design/sizing and costing information was available or sufficient information was available to develop it
Bench or pilot-scale technology was considered in some cases of specific interest.

In order to develop a list of available technologies from which demonstrated technologies may be selected, information was gathered from a number of sources. Data gathered from various sources were not all of the same quality as that required by the MISA Monitoring or Effluent Limits Regulations. Considerable professional judgement was applied in accordance with the principles discussed on page 52 to ensure that the technical capabilities of the processes defined in this report were feasible in Ontario conditions.

2.7.3 BAT selection

The process for selecting BAT options from the list of demonstrated technologies considered primarily their ability to remove contaminants, and secondarily the following goals for an effluent:

Non-lethal to trout and *Daphnia magna*
Effective use of recycling, re-use and reduction, and smallest transfer to other media
Reduction of AOX in effluents from bleached kraft mills
Water conservation.

To the extent feasible, only data published in peer-reviewed scientific and engineering journals were relied upon. However, in an industry such as pulp and paper, where technology is developed by a wide variety of equipment manufacturers, pulp and paper manufacturing companies, research organizations and academics, it was found to be necessary to consider other sources of information to ensure that this report would be up-to-date when published. Refer also to the discussion on page 52.

Process selections need not be based on a full understanding of why a process functions, as long as the engineers feel confident that the selection is appropriate. Such decisions are normally based more on industrial scale empirical evidence than on rigorous scientific analysis of the underlying process fundamentals. In some cases this is the only available approach, because the technology vendor may not make the technology underlying a new technique available to the public.

This makes it very difficult to assess emerging technologies in the context of Best Available Technology. As a consequence, the Ministry of Environment defines BAT as technology that has been demonstrated in full scale operation for approximately 12 months, while allowing that pilot plant or short term industrial scale data may be relevant in some cases. This is a somewhat conservative attitude, and in a few cases, the authors have evaluated technologies that have been demonstrated in pilot plant or in full scale for a short period, e.g. zero-effluent mechanical pulping, bleaching by means of enzymes and others.

In selecting the technologies that were considered to be the Best Available, there was no formal consideration of the economic achievability[23] or the environmental benefits resulting from the reductions in effluent discharges. Technologies which would clearly create a major negative effect on aspects of the environment other than the waterways that this report is focused upon were avoided.

2.7.4 Product modifications

Generally, it was assumed that the mill would not modify the production rates or product mix when selecting suitable technology for effluent discharge control.

It is recognized that there are many potential approaches to optimizing environmental impact of a pulp or paper mill which would involve modifying the product mix, or perhaps terminating some or all of the manufacturing activities on the site concerned. Evaluation of such options would be a vast undertaking, and would require analyses of effects on receiving waters, as well as socio-economic impacts. This was not included in the terms of reference.

Changing consumer demands, particularly in Europe, could potentially increase the demand for different types of paper, or at least variations in current quality standards, particularly for products manufactured without the use of molecular chlorine for bleaching. It is well known that the majority of Ontario pulp and paper products are sold in Canada and the US, as confirmed by Bonsor (1988), and the standard references such as Statistics Canada. The extent of demand for molecular chlorine free paper products in North America is currently less evident than in Europe. However, many pulp manufacturers and customers have expressed the expectation privately that demand for low/no molecular chlorine papers will grow substantially. The authors could not find sufficient data to predict such market trends, and did not consider that it was practicable to predict their effects at the time of writing. Therefore, product modification can not be considered as a viable BAT alternative.

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[23] *Analysis of economic achievability will be the subject of a subsequent report prepared by the Ministry of the Environment, using the capital and operating costs discussed in this report.*

3 MANUFACTURING PROCESSES

SUMMARY Pulp is an intermediate product in the manufacture of paper and paper products. It is manufactured in Ontario by a number of quite different processes, with varying environmental effects. Kraft and mechanical pulp are the two predominant types of wood pulp produced in Ontario, and in the rest of the world. Unbleached kraft pulp is manufactured by separating the wood into its individual fibres by cooking wood chips under pressure and elevated temperature in a digester with strong alkali. The pulp is usually bleached by molecular chlorine, chlorine compounds and related chemicals, and then dried for sale or used on site for papermaking. Mechanical pulps, produced with a wide degree of chemical assistance and by a variety of mechanical pulping equipment are used extensively in Ontario for the manufacture of newsprint. These processes discharge oxygen demanding and toxic substances that may be reduced to very low levels by biological treatment and/or process modifications. Pulp may also be produced by repulping waste paper. Some waste paper will require deinking. This latter process is a significant source of solid waste, and a minor source of oxygen demanding substances.

Paper manufacturing operations which use only pulp obtained from off-site sources as their principal raw material, generally discharge relatively little toxic or oxygen demanding material.

3.1 Various Categories of Pulp and Paper Mills

SUMMARY Paper mills manufacture paper ready for use by printers, industrial packaging plants, or end-use consumers. Products include newsprint, office paper, tissues, and many others. Pulp mills manufacture wood pulp, an intermediate product that is the principal raw material for manufacturing paper. The pulp is generally shipped to paper mills in the form of dry bales. Integrated mills include a pulp mill that provides some or all of its output to a paper mill on the same site.

In Ontario, there are eight paper mills, ten integrated mechanical pulp mills and nine kraft or integrated kraft mills that discharge their effluents "directly" to watercourses, as opposed to municipal sewers.

Distinctions between these three broad categories of mills are not always clear, because it is common for integrated mills to ship a portion of the pulp to remote paper mills, and/or purchase some of their pulp from remote pulp mills. However, the differences are important environmentally, because an integrated mill has opportunities to reduce effluent discharges by recycling between the paper and pulp manufacturing operations. This option is not available when the processes are hundreds of kilometers apart.

Pulp and paper manufacturing may be considered as a series of interrelated unit operations or building blocks, and this approach is used in the following descriptions. A very complete review of North American pulp and papermaking technology is presented in the "Pulp and Paper Manufacture" series of textbooks (Kocurek 1986-89). Readers desiring a more compact review may consult the single volume "Handbook for Pulp and Paper Technologists" (Smook 1988). McCubbin (1983b, 1984) described much of the manufacturing technology with emphasis on environmental protection practices of the Canadian pulp and paper industry.

3.2 Wood Preparation

All mills producing pulp require some form of wood preparation plant. This plant will normally generate some effluent, unless all the wood is obtained as bark-free chips from sawmills. Usually the wood is debarked at the mill site, using either wet or dry processes.

An increasing proportion of the wood used by most pulp mills is in the form of chips from sawmills, although only a few mills rely totally on this source. The sawmills must, of course, debark the logs, but they generally use dry mechanical debarkers. Boise Cascade at Kenora and CPFP at Thunder Bay have manufactured newsprint from dry debarked wood for several years.

Further details of modern wood preparation systems may be found in Bonsor (1988, pg. 27-29). Refer also to page 155 on debarking processes.

Table 4 compares the effluents from the debarking processes that can be used in Ontario. Note the relatively high residual bark in winter conditions for the dry drum debarker. This is acceptable if the mill stock cleaning and screening systems are adequate, but many older ones would require upgrading if a wet drum debarking system was converted to a dry one.

Table 4 Comparison of debarking processes

Parameter	Units	Wet drum	Dry drum	Mechanical ring
Effluent flows	m^3/tonne	3-20	0-5	0
Suspended solids	kg/tonne	15-50	0-10	
BOD	kg/tonne	5-10	0-3	0
Energy consumption	kWh/tonne	20	21	3
Dryness of bark	%OD	40-55	50-55	50-55
Residual bark				
Softwood summer	%wt	0.5-1	0.5-1	0.2-0.5
Hardwood summer	%wt	0.5-1	1-2	-
Softwood winter	%wt	0.5-1	1-2	0.5-1.0
Hardwood winter	%wt	0.5-1	1-4	-

Source: Beak 1978, except that mechanical ring barker data are based on author's experience.

3.3 Principles of Pulping Wood

Converting wood into pulp consists essentially of separating the wood into individual fibres that will be suitable for paper, paperboard, or related products. There are many ways of accomplishing this fibre separation. Some processes that were dominant in the past, and are frequently encountered in literature, are now used very little. These include the traditional low-yield sulphite pulping process that is no longer used in Ontario, except at Kapuskasing.

The following discussion emphasizes processes now used in Ontario, and some are likely to be implemented in the next few years.

Simplistically, one can consider the wood fed to the pulp mill as containing about 45% cellulosic fibre, and the rest non-fibrous components; lignin (20% to 30%), hemicellulose (25%), and extractives (5%). Chemical pulping methods remove most of the non-fibrous material, whereas mechanical processes allow most of the lignin and much of the hemicellulose to remain with the fibre. All the material removed has high a BOD and some of it is toxic to fish.

The **pulping yield** is the weight of pulp produced from a unit weight of oven dry wood, and varies widely for the different processes. There is also some range in yields for each process, depending on the species of raw wood, quality of product required, and technology of the production process.

In pulping systems that do not recover the spent cooking chemicals and soluble material from the wood, the yield is the principal process parameter affecting effluent quality[24]. The quantity of organic material released in a pulping process is inversely proportional to the yield, so that a system operating with a yield of 90% would discharge twice as much organic material as one operating at 95% yield. The BOD of effluent is roughly proportional to the organic discharge for any one type of process within the practical range of yield. The organic matter removed from the raw wood in the higher yield processes degrades more rapidly than that from low-yield processes. Therefore, it exerts a greater BOD load per unit weight than the organics from a low-yield process. In pulping systems that recover the spent liquors, effluent quality is more dependent on the efficiency of the recovery process than on the pulping yield.

If the pulp is bleached with chlorine, as in some deinking mills, and as in most kraft and low-yield sulphite mills, the amount of chlorine used has a major effect on effluent quality.

3.4 Chemical vs Mechanical Pulping Processes

Traditionally, pulping processes have been divided into two principal categories: chemical and mechanical.

In **mechanical pulping**, the fibres are separated by application of mechanical energy under wet conditions. The fibres are literally torn apart, one from the other. In true mechanical pulping only about 5% of the weight of the original wood is lost as dissolved organics and a few percent rejected in solid form. Product yields are typically 90% to 96%. The most popular mechanical pulping processes are groundwood and TMP.

Chemical pulping separates the wood fibres by breaking down the bonds between them with chemical reactants, generally at temperatures of about 150 to 200 deg C. Up to 60% of the mass of the wood can be converted into soluble organics by such a process, so the yield of pulp can be as low as 40%. Kraft is by far the most widely used chemical pulping process. Sulphite is the only other chemical pulping process used in Ontario.

This simple classification into distinct chemical and mechanical categories is now technologically obsolete because of the number of hybrid sulphite/mechanical processes developed over the past 25 years. However, the terminology is still widely used and accepted.

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[24] *All kraft mills, and a very few sulphite mills recover the spent cooking chemicals and soluble matter. The only sulphite mill within the scope of this study which recovers these spent liquors is at Spruce Falls.*

3.5 Kraft Pulp

SUMMARY The kraft process, also known as the sulphate process, is the dominant chemical pulping process in Ontario and the rest of the world. It relies entirely on chemical actions to separate the pulp into fibres, and is most commonly used to produce bleachable grades of pulp. Current chemical recovery and bleaching technology was developed in the 1930s and 1940s, and industrial implementation has become widespread since 1945. Production of pulp and discharge prevention at source of air and water pollutants are inextricably intertwined. The potential for minimizing effluent discharges is greater for kraft mills than for other types.

The kraft process is used to manufacture about 50% of the pulp produced in Ontario, and is the dominant chemical pulping process in Canada and all other major pulp producing countries. This process covers a fairly narrow spectrum, with yields ranging from about 40% to 55%. The kraft process is compared with others in Table 14 on page 105.

3.5.1 Debarking and chipping

For the kraft pulping process, the log is debarked and chipped as discussed on page 155 and reduced to wood chip fragments generally 12 to 18 mm in length. The environmental significance of chip quality, is discussed on page 157.

3.5.2 Kraft process description

Kraft pulping utilizes an alkaline solution referred to as white liquor, typically about 10% concentration of Na_2S and NaOH, to delignify the wood for fibre separation. The series of cycles characteristic of this process is schematically illustrated in Figure 8.

The spent cooking liquors (known universally as black liquor) are separated from the pulp by washers following cooking in the digester, and are treated in the chemical recovery system. The recovery system regenerates the cooking chemicals of Na_2S and NaOH while utilizing the heat value of the organic residue to generate steam for the process. The chemical recovery system is described on page 92.

In the cooking process, the extent to which the lignin is separated from the pulp is expressed as the Kappa number. Typical current Kappa numbers are shown in Table 6 on page 70. The Kappa number is approximately proportional to the quantity of lignin which remains attached to the pulp fibres, either because it was not dissolved in the cooking process, or because it was so closely bound to the fibres as to be difficult to wash out. Low lignin content is desirable for pulps which will subsequently be bleached in the interests of reducing bleach chemical consumption and, where chlorine is used, the consequent discharges of organochlorines.

The **Kappa number** is a widely used test (TAPPI 1988) which has been used as the measure of the content of ligneous and related organic material for most mill operations and research work in this field. The permanganate number (or "K Number") is commonly used in mill operations as a control test because the analytical procedure is simpler. Although it is related to the lignin content, it does not have a linear relationship with the Kappa number. When extended delignification is being practiced by differing processes, the Kappa number provides a better representation of the pulp characteristics for the purpose of predicting effects of process modifications than the permanganate number. For this reason, only the Kappa number is used in this report.

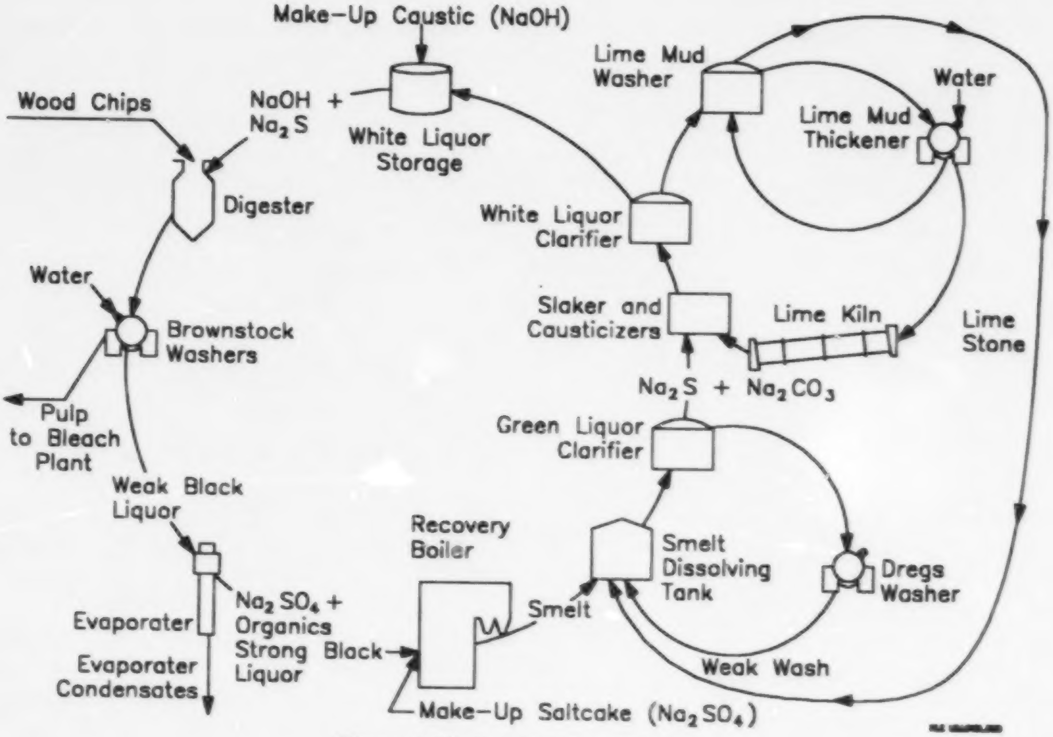

Make-Up Caustic (NaOH)
Wood Chips
NaOH +
Na₂S
White Liquor Storage
Digester
Lime Mud Washer
Water
Lime Mud Thickener
White Liquor Clarifier
Water
Brownstock Washers
Slaker and Causticizers
Lime Kiln
Lime Stone
Pulp to Bleach Plant
Na₂S + Na₂CO₃
Green Liquor Clarifier
Weak Black Liquor
Recovery Boiler
Smelt Dissolving Tank
Dregs Washer
Evaporater
Na₂SO₄ + Organics
Strong Black Liquor
Smelt
Evaporater Condensates
Weak Wash
Make-Up Saltcake (Na₂SO₄)

Figure 8 Kraft process concept

In general, lowering the Kappa number of a pulp prior to bleaching leads to lower discharges of pollutants, particularly soluble organics (COD, colour, resin acids and others), and, indirectly, chlorinated organics (AOX). The optimum Kappa number for the pulp leaving the digester(s) depends on many factors, including the existence or absence of downstream processes for the reduction of Kappa number. The ability of the mill's recovery boiler(s) to burn the additional quantities of lignin removed from the fibres where cooking is extended to lower Kappa numbers, must also be considered. Several processes, including oxygen delignification and extended cooking, are available for reducing the Kappa number. These are discussed in Chapters 5 and 6.

3.5.3 Digesters

The cooking process can be either batch or continuous. In the continuous cooking process, shown in Figure 32 on page 168, the chips are pre-heated in a steaming vessel before entering the digester. Pre-steaming removes air, non-condensible gases and volatile constituents such as the terpenes. After entering the continuous digester the chips are impregnated with cooking liquor ("white liquor") at a controlled temperature to ensure uniform penetration of the cooking liquor. After impregnation, the temperature is raised to the cooking temperature of around 165 deg C by indirect heating of circulated cooking liquor and held there for about one hour. The pulp is then quenched to about 125 deg C with wash liquor.

In most continuous digesters installed after 1970, diffusion washing is then carried out in the lower region of the digester, removing a considerable proportion of the spent chemicals. The wash temperature in the lower zone of the digester is 80 to 85 deg C. This ensures suitable blow conditions with little or no mechanical damage to the fibres.

In batch cooking, shown in Figure 11 on page 73 the chips and cooking liquor are charged into the digester which is then sealed and raised to operating pressure and temperature according to a pre-determined schedule. After digestion the pulp is blown hot into a blow tank where it is diluted with black liquor and then pumped to the washing system. Where batch cooking is used, there are several digesters, to maintain a relatively continuous flow of pulp to the downstream equipment, which is invariably designed for continuous operation.

3.5.4 Anthraquinone

Anthraquinone is widely used in the pulp and paper industry in Japan, and to some extent elsewhere. It was well established in the textile industry before being used in the pulp industry. It is normally used in a soluble form commonly known as SAQ. In the context of this report **the principal interest in anthraquinone is its potential to compensate for increases in recovery boiler load at a predictable cost.**

In the kraft industry, the increased reaction rate attainable with anthraquinone has been exploited to increase the pulp yield, thus reducing the quantity of dissolved wood which has to be burned in the recovery boiler. It may also be used to increase production in mills with limited capacity in recovery boiler or cooking liquor preparation systems. Despite the lack of published information, the authors are aware of many mills in North America which have successfully run full scale trials with SAQ. The pulp companies running the trials have generally concluded that its use is technically feasible, but that the cost of the SAQ exceeds the benefits in increased yield. In Japan, a high proportion of kraft mills use SAQ, presumably because the high wood costs and the relatively low costs of SAQ make it more economically attractive.

Holton and Chapman (1977) and Ringley (1991) showed that anthraquinone could be used to improve mill pulping yields. In the kraft industry, the promise of increased yield offers a means of reducing the load of dissolved wood solids on the recovery boiler, and the quantity of cooking liquor that has to be prepared. This is useful to compensate for the introduction of effluent quality improvement processes for prevention of discharges at source, such as oxygen or ozone delignification, which increase recovery boiler load by up to several percent. Anthraquinone can be used to compensate for up to 7% increased load. The authors are not aware of any data showing the effect of anthraquinone on extended cooking processes, so have not assumed its use in estimating costs of process modifications in this report.

Table 5 Cost of anthraquinone for compensating recovery boiler load

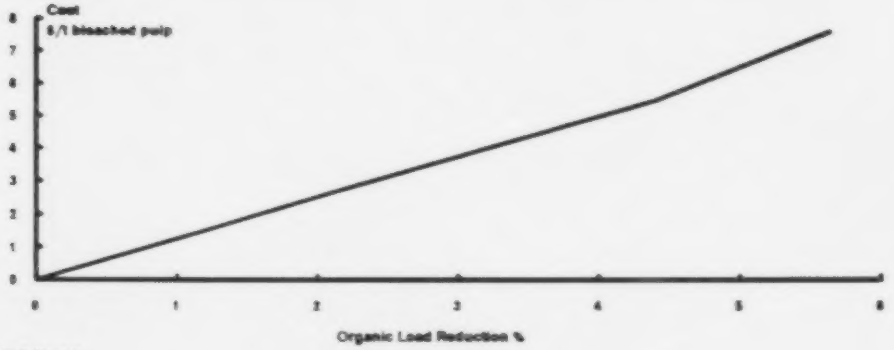
		Anthraquinone Charge, % on wood				
	Units	**0**	**0.03**	**0.04**	**0.06**	**0.08**
Yield	%	48.	48.56	48.75	49.13	49.45
Wood input	ODt/day	2,083	2,059	2,051	2,036	2,022
Effective alkali charge	% on wood	14.5	14.13	14.	13.75	13.5
Unit price of SAQ	$/kg	11	11	11	11	11
Cost of softwood at mill	$/ODt wood	140	140	140	140	140
Organics to black liquor	ODt/day	1,062	1,038	1,030	1,015	1,002
Actual chemical charge	ODt/day	569	548	541	527	514
Black liquor exit digester	ODt/day	1,631	1,586	1,571	1,542	1,516
Black liquor solids : pulp	kg/tonne	1,631	1,586	1,571	1,542	1,516
Boiler load reduction (organic)	%	0	2.2	3	4.4	5.6
Anthraquinone consumed	kg/day	0	618	821	1,221	1,618
Cost of anthraquinone consumed	$/day	0	6,796	9,026	13,435	17,796
Wood cost	$/day	291,667	288,303	287,179	284,987	283,114
Saving on wood	$/day	0	3,364	4,487	6,679	8,552
Evaporator steam @ $9/tonne steam	$/day	18,000	17,792	17,723	17,588	17,472
Saving in evaporator steam	$/day	0	208	277	412	528
Lime kiln fuel	$/day	10,000	9,629	9,507	9,266	9,037
Savings in lime kiln fuel	$/day	0	371	493	734	963
NaOH released for oxygen delignification	kg NaOH/t	0	12.4	16.5	24.5	32.2
Net cost of anthraquinone	$/day	0	2,854	3,768	5,609	7,753
Cost for bleached pulp	$ /ADt	0	2.79	3.69	5.49	7.58

For 1000 ODt/day softwood pulp.

Source : Holton 1983, Bonsor 1988, costs updated by authors.

Table 5 shows the costs for additions of various anthraquinone charges to the digester and the corresponding **reductions in boiler load** which would result, assuming production was held constant. Notice that the effective alkali charge required is also reduced by the use of SAQ, which will generally **compensate for the additional load imposed on the white liquor preparation equipment** for supply of white liquor for oxidizing prior to use in an oxygen delignification stage. These data are based on research and mill experience with conventional cooking, and probably do not apply to digesters using extended cooking. The authors were unable to find published data concerning the use of anthraquinone with extended cooking.

The data from Table 5 concerning boiler load reduction and net cost are summarized in Figure 9.



AQ.XLS Chart 2

Figure 9 Cost of anthraquinone required to reduce recovery boiler loading

There are a number of other applications that have been developed or suggested for the use of anthraquinone. Many of these have involved the mechanical-sulphite group of pulps and take advantage of the increase in pulping rate of reaction experienced with the addition of small quantities of this chemical to the pulping cycle for product quality enhancement purposes. The increased reaction rate is accomplished while maintaining and sometimes enhancing desirable pulp qualities. For example, anthraquinone has become the basis of variations in the sulphite process aimed at raising pulp strengths to more competitive levels. None of these other applications has any great effect on mill effluents.

3.5.5 Pulp washing and screening

SUMMARY. The pulp is washed to separate the black liquor from the fibres, then the fibres are processed in screens to remove partially cooked fibres, shives and other material which can not be bleached satisfactorily. The efficiency of the brown stock washing system is one of the keys to the operation of a kraft pulp mill with minimal effluent discharge. The current washing and screening processes have been in use for over forty years, but the equipment available has been improved substantially over the past fifteen years. Equipment in the Ontario mills ranges from the best modern systems with washer losses under 5 kg soda/tonne pulp to antiquated equipment with losses up to ten times higher.

The lignin and related material separated from the fibres during cooking (known as "black liquor") must be either recovered from the pulp stream by the washing system and routed to the chemical recovery department or they will be discharged to the sewer in the screening system or subsequent operations. The black liquor is toxic to fish so high losses from the washing area tend to have a large impact on effluent quality.

A simplified process flowsheet of a modern brown stock washing and screening system is presented in Figure 10. Note that most pipes and tanks contain black liquor in some form, so control and recovery of accidental spills is essential to protect effluent quality. The pulp from the digester contains in the order of one tonne black liquor solids per tonne of fibre, at a consistency of about 10%, so that there are 9 tonnes water per tonne pulp. The wash water enters the second (last) diffusion washer, and flows counter-current to the pulp, to the first diffusion washer and thence to the washing stage in the lower part of the digester body. In each washing stage, the wash water picks up more dissolved black liquor solids and the pulp becomes successively cleaner. In the system described, about 98% of the black liquor formed in the digester would be separated from the pulp, but the remainder, including about 10 to 25 kg of organics per tonne pulp, would carry on to the screens.

The screens and related pulp cleaning equipment can only operate at low consistency, so water or wash liquor has to be added to dilute the pulp to around 2% solids, that is to say about 50 tonnes water per tonne pulp. Refer to Figure 11 on page 73 and Figure 10. After screening, the pulp is rethickened on a decker to about 12% dry solids, so that excess unbleached white water is produced. In the past, a few mills simply added fresh water to dilute the pulp after the washer and discharged the excess to the sewer from the decker. Even the less efficient operations today recirculate much of this water. However, unless **all the unbleached white water is recycled, the effect of this dilution/rethickening operation is that most of the organics which remain in the pulp after the last washing stage are sewered along with the unbleached white water**. This is generally considered to be environmentally undesirable, and in the 1970s context when BOD was the principal criteria for defining effluent quality, this was probably true. Today, however, it may be better to discharge these organics to the sewer in the unchlorinated form, rather than to have them carry on with the pulp to the bleach plant, if they will be chlorinated and then discharged.

There has been a general trend toward increasing the efficiency of existing brown stock washer systems, by installing additional washing stages, better washing equipment, and by improving instrumentation. Most new systems are designed to operate with a loss of under 7 kg pulp free soda, expressed as sodium sulphate per tonne of pulp, and most Ontario mills report losses of 6 to 10 kg/tonne. Twenty years ago, a soda loss of 50 kg/tonne was not uncommon.

A systems approach to the design of the complete pulping, washing, screening and liquor recovery cycle is essential if the optimum design of the washing and screening area is to be attained. The necessary theoretical process knowledge was available by about 1960, but the amount of work and time lags necessary for the calculations of the many possible alternatives, limited the use of this knowledge in most new mill design projects. Since the late 1970s, cost effective and efficient computer based process simulation technology has been available, and is being used increasingly for the design of new mills and optimization studies of existing installations.

The **closed screen room** concept has been discussed in the literature for many years, and is used in more than half the Ontario mills. Referring to Figure 10, if the wash water entering the second diffusion washer is replaced by unbleached white water from the decker, and the process is controlled so that all the dilution required for the screens is provided by recycled unbleached white water, then the screen room process will be "closed". In this case, the fresh wash water required to carry the black liquor solids back to the chemical recovery system would be added to the decker showers.

It is not difficult to design such a closed screen system on paper, and it is quite common for mill design flowsheets to show the only exits of liquid from the washing and screening process as being with the washed pulp and the weak black liquor which goes to the evaporators. However, the operation of a kraft screen room system without any excess water flowing to the sewer from the screening system is impractical unless all aspects of the design of the system and the equipment selection are appropriate.

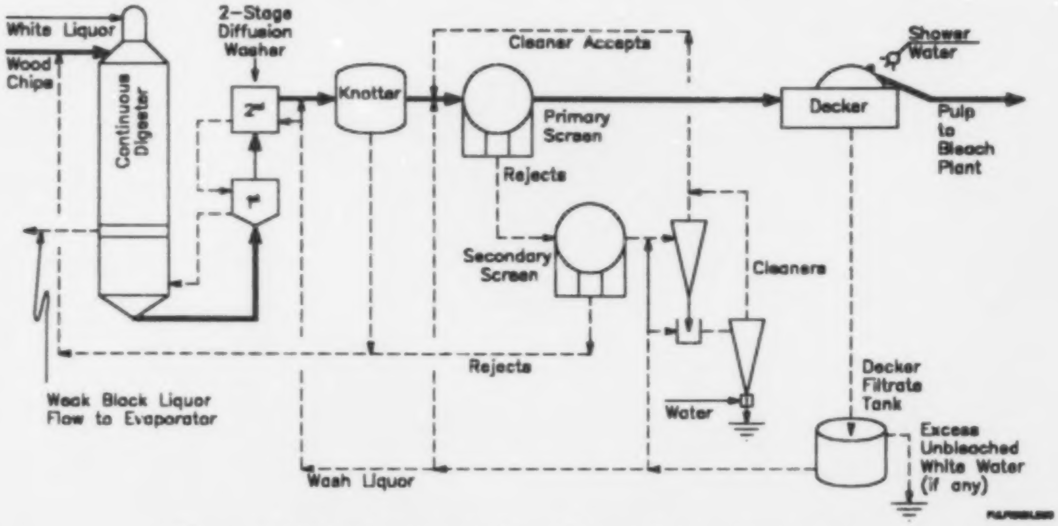

White Liquor
Wood Chips
Continuous Digester
2–Stage Diffusion Washer
2nd
1st
Knotter
Cleaner Accepts
Primary Screen
Rejects
Secondary Screen
Cleaners
Rejects
Shower Water
Decker
Pulp to Bleach Plant
Decker Filtrate Tank
Water
Weak Black Liquor Flow to Evaporator
Wash Liquor
Excess Unbleached White Water (if any)

Figure 10 Modern brown stock washing and screening system

When discussing closed screening, it is essential to recognize that the term "closed screen" is not synonymous with a "closed screening process". The term "closed screen" refers to the construction of the individual screening device (identified as "primary screen" or "secondary screen" in Figure 10) where the screen operates under pressure in a closed vessel with no opportunities for overflows or other uncontrolled discharges except in the unlikely event of a rupture of the vessel. An "open screen" is constructed so that the screening surface is open to atmosphere, increasing the risk of overflows, particularly where the stock has a tendency to foam.

The principal variables controlling the feasibility of operating the screening systems as a closed process are the soda loss of the last washer upstream of the screens, the wood species and type of washing and screening equipment. It is always environmentally desirable to minimize washer losses, and in current practice a loss of under 5 kg Na_2SO_4/tonne pulp is considered excellent and is attainable with modern equipment. Pulp, which is to be further delignified with oxygen, must be well washed to avoid degradation of strength, so that it is often necessary to upgrade brown stock washing systems when retrofitting oxygen delignification. If modern pressure screens are used, a higher soda loss prior to screening is more tolerable than where the older type of open centrifugal screens are used. In resinous types of woods, it is usually impracticable to operate a screening system without a continuous overflow to the sewer from the decker when open type screens are used.

Where the washing and screening system can be operated on a closed cycle, it results in the screen room and decker becoming an integral part of the washing system. Adding an additional washing stage will typically reduce the effluent BOD from this area by about 60% relative to a system where there is a substantial overflow to the sewer from the decker seal tank. Most of the existing mills which have oxygen bleaching systems operate in this way, and an increasing number of others do so as well.

The key difference between open and closed screening systems is that the open screen room would have a substantial overflow from the decker filtrate tank, typically 5 to 15 m³/tonne pulp. Most of the residual organic material which is not recovered in the pulp washers, flows to the sewer in this stream and is one of the major sources of BOD and toxicity in the mill effluent.

It is generally desirable to operate the system so that there is no overflow of decker filtrate. However, a careful analysis of the complete black liquor system is required to determine the optimum method of operation of the available equipment. In a bleached kraft mill it may be more environmentally desirable to discharge some of the screen room decker filtrate than to have the residual black liquor reach the bleach plant, and be discharged in chlorinated form.

Foam overflows are common in some mills and contribute to effluent toxicity since the foam is rich in resin acid. Modern systems minimize foam generation by avoiding free falling liquid streams to the extent feasible and avoiding the open screens and vacuum washers which lead to air entrainment. Overflows are generally connected to other tanks, with the ultimate overflow at a controlled point, usually the decker filtrate tank.

Improvements in closure of brown stock screening systems have taken place in several Ontario mills in recent years, and mills which consider their brown stock screening system to be closed are indicated in Appendix A. Experience has shown that only the best systems operate on the closed process concept at all times.

3.5.6 Traditional washing equipment

Traditionally, kraft pulp has been washed on a series of countercurrent vacuum drum washers. The pulp is alternately diluted and rethickened on drum filters, with wash water flowing countercurrent to the pulp. It is applied to a mat of pulp on the drums to displace the black liquor retained between the fibres.

This type of equipment uses large recirculating flows of black liquor and pulp (about 100 m³/tonne per stage) which can be a major source of accidental spills of fibre and organic material. Up to 99% of the washable organic material can be recovered from the pulp with this equipment, but this would normally require five stages of drum washers. Most mills have only three or four stages, so only 93% to 98% of the organic material is recovered and the remainder is discharged to the sewer.

3.5.7 Diffusion washing equipment

Since the early 1970s, many new installations of brown stock washing equipment have used continuous diffusion washers. The earlier units operated at atmospheric pressure, while some of those installed in the 1980s operate under pressure.

In a typical atmospheric unit, pulp enters the conical bottom of the unit and passes slowly upwards through the diffuser(s). There may be one or up to three in series, installed vertically above one another. The washing medium is introduced into the pulp through rotating distribution nozzles, displacing the black liquor in the pulp both outwardly and inwardly to one of several screen rings. Displaced liquor is collected and then pumped to the preceding washing stage. The washed pulp is discharged at the top of the diffuser tank.

A feature of diffusion washing is that the pulp remains at about 10% consistency throughout the washing process, eliminating the high flows of recycled filtrate which are required in the traditional drum washing system, decreasing pumping power and substantially reducing the volume of potential overflows.

A multi-stage diffusion washer system is also used in a few cases to wash batch digester produced pulp. Stock from the batch digester blow tank is pumped to the inlet of the diffuser tower. The pulp is thickened to approximately 8% to 9% consistency with the first diffuser. The subsequent washing stages operate as previously described.

Figure 10 is a simplified representation of an early 1980s kraft pulping, washing and screening system typical of the recent installations in Canada, utilizing diffusion washers and closed pressure screens and knotters. Note that even with diffusion washers the flow of decker filtrate (frequently described as unbleached white water in the literature) is large (typically 40 m^3/tonne) relative to the incoming shower water flow (typically 10 m^3/tonne) so that any imbalance in the system is liable to cause substantial overflows to the sewers.

The **pressure diffusion washer** is an equipment variation of the conventional diffusion washers described above for single stage retrofit. The washing performance is similar to the diffusion washer, but cost in retrofit situations is usually lower and installation is simpler. The pressure diffusion washer has the potential to allow mills to improve washing efficiencies at lower cost than in the past. A 500 tonne/day unit would be approximately 1.5 m diameter and 11 m high, which is quite small relative to other types of washer, and lends itself to shop fabrication, which generally reduces total installed costs, and facilitates retrofitting in an existing mill. The washing equipment is contained within a pressure vessel allowing operation at much higher temperatures than is possible for atmospheric washers, with beneficial effects on washing efficiency. The closed design eliminates most of the risks of spills which are relatively frequent in traditional drum washing systems.

The pulp at a consistency of 10% to 12% enters the top of the pressure diffuser and moves downward as a mat between the stationary central body and the moving perforated cylindrical screen, and is removed at the bottom of the vessel. The wash medium flows from the central body, through the pulp mat, through the moving cylindrical screen, and is extracted continuously through an extraction header.

The **belt washer** is constructed following the same basic principles used to make sheet forming devices for papermaking. Some of these devices are like a Fourdrinier wire section in appearance. These, and similar devices, are fitted with a forming area and have vacuum boxes as part of the wire carrying table. The boxes are placed under a differential pressure that is applied by blowers. There are several variations in design, but the main features are generally the same.

Belt washers are capable of providing at least 7 washing stages, so one single belt washer can replace a conventional multistage drum washing system. This results in well washed stock achieved at a very low dilution factor. The dilution factor is about half that of standard washing equipment which means a reduced load to the evaporator system and to the effluent treatment facilities. These devices are not suitable for incremental increases in washing capacity, but represent an efficient replacement of an overloaded, or worn out system. Belt washers are included in the technology trains for mills with apparently deficient washer systems; that is, with washer losses of 25 kg or greater equivalent salt cake. There are now several competing vendors of belt washers using various trade names.

Defoamers are frequently used to control foaming in the pulp washing and screening areas. Some of these additives were found to be contaminated with DBD (Dibenzo-p-dioxin) and DBF (Dibenzo-p- furan). In the bleach plant these precursors are converted by chlorine to TCDD/TCDF, or chlorinated dioxins/furans. (Voss 1988).

When these products were identified as a source of precursors, pulp and paper mills switched to defoamers that were produced from raw materials free of DBD and DBF. These contaminates were traceable to recycled oil and/or specific oil sources, and a switch to precursor-free oil resolved the problem. Water based defoamers are available and a number of mills had switched to these products for pitch control reasons prior to the dioxin concern.

All mills in Ontario use only defoamers that are free of precursors, and the regulations currently proposed by Environment Canada will presumably ensure that this practice continues.

3.6 Extended Delignification

Since the early 1970s, several processes have been developed to extend delignification of the kraft pulps beyond the conventional levels, all of which are environmentally desirable in most circumstances where the pulp will be bleached in subsequent processes. These are summarized in Table 6 and are discussed in detail later in this report. The process described as "extended cooking" is also known as "extended delignification" or more often by one of the following trade names:

Modified Continuous Cooking	MCC	Kamyr
Rapid Displacement Heating	RDH	Beloit
Super Batch	------	Sunds Defibrator

Table 6 Extended delignification processes

Process name	Process concept	Attainable Kappa number	
		Softwood	Hardwood
Traditional	Traditional batch or continuous cooking	30	18
Extended cooking	Modification to digester equipment and operating procedures to add white liquor progressively to the wood, permitting lower Kappa numbers without loss of strength	15	8
Hot alkali extraction	Soak unwashed pulp in 150 deg C for about 30 minutes with white liquor to liberate dissolved lignin within fibres so that it can be washed out in subsequent washing stages	Up to 50% drop, still under laboratory investigation	
Medium consistency oxygen delignification	Application of gaseous oxygen to dissolve lignin at approximately 12% to 15% consistency	45% drop	35% drop
High consistency oxygen delignification	Application of gaseous oxygen to dissolve lignin at approximately 25% to 30% consistency	50% drop	35% drop
Enzyme bleaching	Solubilize lignin by addition of enzymes with xylenese activity, for subsequent washing with water	Full scale trials indicate 20% drop not yet commercial	
Ozone delignification	Application of ozone to dissolve lignin	5-10	

This table is relevant only to bleachable grades of pulp, not to unbleached packaging or linerboard.
Ozone based on laboratory bleaching, no full scale data available at the time of writing.

3.7 Bleaching of Kraft Pulp

SUMMARY In Ontario kraft mills the pulp is bleached immediately after the washing/screening operation in a continuous bleach plant installed adjacent to the pulp mill.[25] *The conventional bleaching process is the source of about half the BOD, all the organochlorines, most of the colour and much of the toxicity in the effluent from a typical bleached kraft mill. In bleach plants, the lignin is first converted to compounds which are soluble in alkali by treatment with chlorine and chlorine dioxide, and then washed out with sodium hydroxide (caustic). The process is repeated two or three times with sodium hypochlorite and/or chlorine dioxide as the bleaching agent. There is a trend toward extending delignification in the prebleaching stages to reduce the quantities of chlorine based chemicals used for bleaching, effectively replacing as much as possible of the chlorine with other bleaching agents, such as oxygen, or hydrogen peroxide. In some cases, chlorine dioxide is used to substitute for all of the molecular chlorine.*

The basic technology of the various bleaching processes were described by Kocurek (1986-89), McCubbin (1983b), Bonsor (1988) and many other authors, and it is assumed that the reader is familiar with them.

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[25] *The Domtar Red Rock mill is an exception in that only a small proportion of the pulp is bleached, and the remainder is used in an unbleached form to manufacture linerboard.*

3.7.1 Bleaching terminology

Table 7 shows the abbreviations widely used in discussing bleaching sequences, and which have been adopted in this report[26]. A single washing stage is assumed between each unit operation unless otherwise indicated.

Table 7 Abbreviations for bleaching unit operations

Abbreviation	Unit operation
C	Chlorination stage, where pulp is treated with gaseous, molecular chlorine, primarily to chlorinate the residual lignin, so that it can later be solubilized.
E	Caustic Extraction. Dissolution of reaction products with sodium hydroxide.
E_o	As "E" above, with the addition of about 5 kg/tonne elemental oxygen. Relatively new (1980s) technology which has rapidly become universal in Canada and popular elsewhere.
O	Treatment of pulp with elemental oxygen, in alkaline conditions.
Z	Treatment of pulp with ozone, under acid conditions.
D	Reaction with chlorine dioxide, applied as an aqueous solution.
C/D	Chlorination stage with chlorine dioxide.
C_d	Chlorination stage with chlorine dioxide addition after Cl_2.
D_c	Sequential addition of chlorine dioxide followed by chlorine.
H	Reaction with hypochlorite (normally sodium).
P	Reaction with hydrogen peroxide.
Q	Chelating agents such as EDTA.
Y	Reaction with dithionite (also known as hydrosulphite).
W	Wash stage. (Indicated only where a washer would not normally be expected, e.g. WW where two stage washing is installed).
N	No-wash (Indicated only where a washer would normally be expected).

Subscripts frequently used to indicate percentage substitution of molecular chlorine where relevant for example C_{d70} would imply 70% substitution of molecular chlorine with chlorine dioxide.
Most mills use chlorine dioxide in the C stage, and the abbreviation "C" is often loosely used to refer to a C/D stage.

The term **oxygen bleaching** is widely used to refer to extended delignification by oxygen, but this is considered to be a **pre-bleaching technology**, or **delignification**, and it has been discussed separately.

Washed softwood pulp arriving at the bleach plant in Ontario mills[27] generally contains about 8% by weight of lignin and related material which gives it a brown colour, similar to that of the familiar paper grocery bag. This lignin must be removed without excessive degradation of the fibres if the pulp is to be suitable for production of printing papers, either white or lightly coloured.

To bleach kraft pulp, the unwanted lignin is first converted to compounds which are soluble in alkali, by treatment with molecular chlorine or chlorine dioxide, and then washed out with sodium hydroxide (caustic). The pulp is then further bleached with hydrogen peroxide, sodium hypochlorite or chlorine dioxide, and washed again in alkali conditions. Subsequent treatment is usually by chlorine dioxide, and where there are two dioxide stages, an intermediate alkali extraction stage with a washer is usually employed. The kraft mill flowsheet in Figure 11 includes a typical bleach plant. There are many bleaching sequences used in kraft pulp mills, and no two mills in Ontario use the same sequence, as indicated in Appendix A.

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[26] *Subscripts 1,2 etc. are used to indicate first, second .... stages using the same bleaching agent* (E_1, E_2....).

[27] *The E. B. Eddy mill at Espanola is an exception because it uses extended cooking and oxygen delignification.*

Each washing stage generates an effluent stream, the washer filtrate, which contains the soluble matter washed out of the pulp. In the past, the filtrate from each washer flowed directly to the sewer, but today mills practice an increasingly intensive recycle of filtrates. Generally the low pH effluents from the chlorination, and chlorine dioxide stage washers are categorized as the "acid sewer", while the others are considered as the "alkali sewer" in the technical literature.

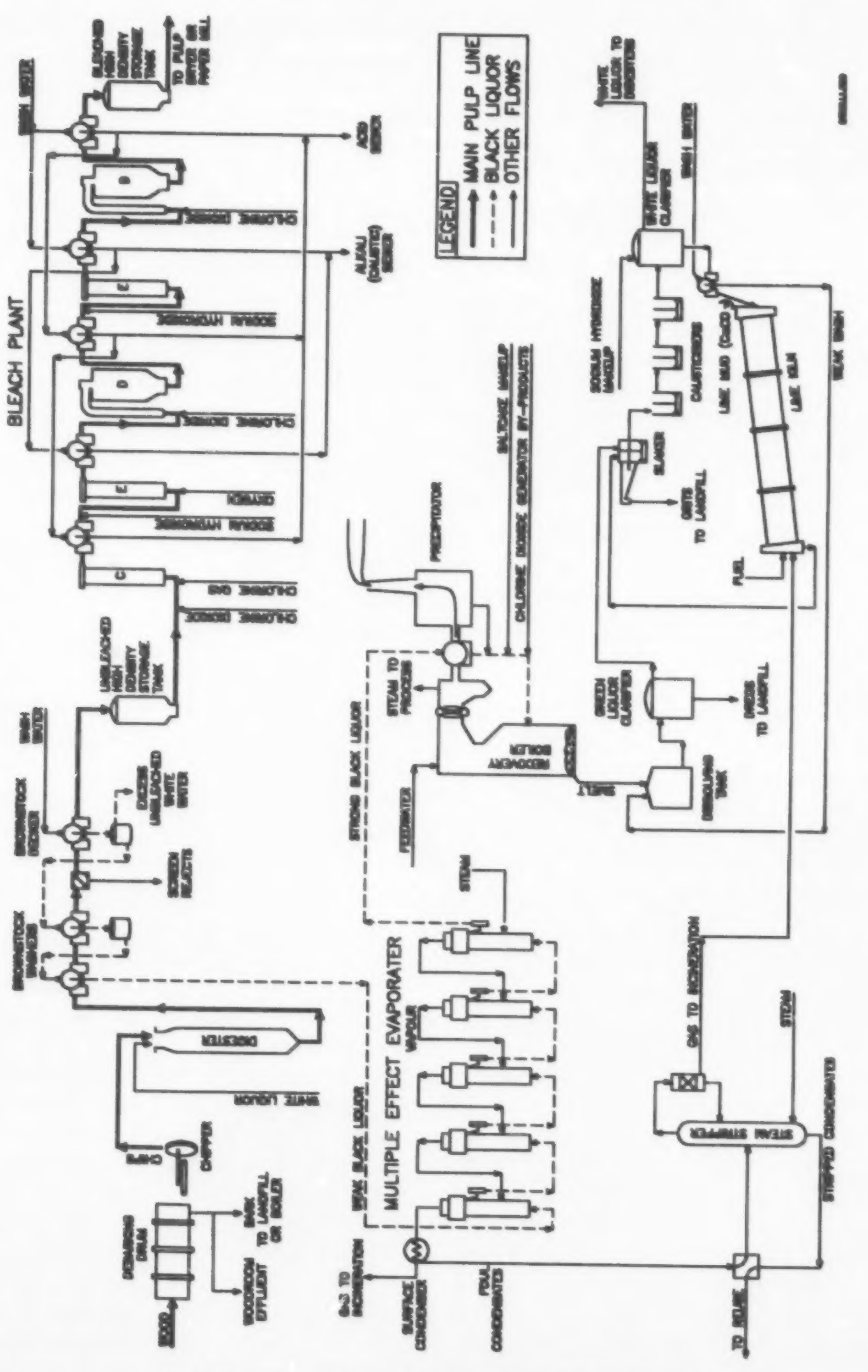
The quantities of chemicals required to bleach the pulp depend on wood species, quality of unbleached pulp, product quality targets and the bleaching equipment installed. Typically about 100 kg of molecular chlorine/tonne pulp or equivalent oxidizing power in some form, is required to bleach softwoods to market quality, while hardwoods require substantially more.

3.7.2 Pulp quality

SUMMARY The brightness of the finished pulp is a key criterion in its marketability, particularly in the customer's eyes. Concerns about the ability of the oxygen delignification process to produce sufficiently bright and strong pulp have caused many companies to avoid using this process although it has a number of environmental advantages, and is used in over 100 mills around the world. If the normal target brightness for market pulps could be reduced from the traditional 90 ISO to 80, then the AOX discharges to the effluent could be reduced by a few percent, but the total AOX discharge to the environment would probably rise slightly, and there would be no change in the discharges of dioxins and furans.

Ontario kraft pulp is sold in the competitive international market, and is subject to the demands of papermakers and consumers of the end product, whether technically sound or not, so it is probably impractical for Ontario to legislate market quality.

An elementary understanding of the approach used to measure **brightness** is necessary to analyses the technical literature on the environmental aspects of pulp bleaching. When a surface has the ability to fully and diffusely reflect all colours in the same proportion as they are contained in sunlight, the reflector is said to be pure white (such as magnesium oxide). Absorption of one or more wavelengths will produce observable colour changes. The assessment and comparison of brightness levels requires the definition of a measuring system, a reference standard, and suitable testing equipment.


BLEACH PLANT
LEGEND
MAIN PULP LINE
BLACK LIQUOR
OTHER FLOWS
WOOD
DEBARKING DRUM
BARK TO LANDFILL OR BOILER
WOODROOM EFFLUENT
CHIPPER
CHIPS
WHITE LIQUOR
DIGESTER
BROWNSTOCK WASHERS
SCREEN REJECTS
BROWNSTOCK DECKER
EXCESS UNBLEACHED WHITE WATER
WASH WATER
UNBLEACHED HIGH DENSITY STORAGE TANK
CHLORINE DIOXIDE
CHLORINE GAS
C
SODIUM HYDROXIDE
OXYGEN
E
CHLORINE DIOXIDE
D
SODIUM HYDROXIDE
E
CHLORINE DIOXIDE
D
ALKALI (CAUSTIC) SEWER
ACID SEWER
WASH WATER
BLEACHED HIGH DENSITY STORAGE TANK
TO PULP DRYER OR PAPER MILL
WEAK BLACK LIQUOR
MULTIPLE EFFECT EVAPORATER
VAPOUR
STEAM
GAS TO INCINERATION
SURFACE CONDENSER
FOUL CONDENSATES
STRONG BLACK LIQUOR
FEEDWATER
STEAM TO PROCESS
PRECIPITATOR
RECOVERY BOILER
SMELT
DISSOLVING TANK
GREEN LIQUOR CLARIFIER
DREGS TO LANDFILL
CHLORINE DIOXIDE GENERATOR BY-PRODUCTS
SALTCAKE MAKEUP
SLAKER
GRITS TO LANDFILL
SODIUM HYDROXIDE MAKEUP
CAUSTICIZERS
WHITE LIQUOR CLARIFIER
WHITE LIQUOR TO DIGESTERS
WASH WATER
LIME MUD (CaCO3)
LIME KILN
FUEL
WEAK WASH
GAS TO INCINERATION
STEAM
STEAM STRIPPER
STRIPPED CONDENSATES
TO SEWER

Batch digesters, conventional bleaching and traditional recovery boiler

Figure 11 Typical kraft mill flowsheet

Standard Brightness in the pulp industry has been arbitrarily chosen to be the reflectance observed from a sample when illuminated with a light wavelength of 457 nanometers (nm) and backed by an opaque layer of its own kind.

The major standards are:

The General Electric Brightness meter which has given way to new technology reflectance meters
The Elrepho photoelectric reflectance photometer, which is popular in Canada
The ISO standard, used in North America for market pulps and popular in Scandinavia.

The differences in brightness values obtained by these three meters are usually only about one point on the scale 0 to 100. This apparently small difference is occasionally significant in the case of market kraft pulp. There are no absolute conversion factors between any two of these standards, but as a rule of thumb, 92 GE = 91 Elrepho = 90 ISO.

It is generally considered in the industry that market kraft pulp must be 90 brightness or higher to be competitive on the international market. Integrated mills who use their pulp on-site are able to use a little lower brightness for the same paper grades since loss of pulp brightness in shipping and storage is avoided. Except for a few integrated mills producing special grades of writing and printing papers, it is usually possible to meet customer requirements using pulp with brightness in the 82 to 86 range.

The demands for high brightness are brought about by marketing pressures related to attractive packaging and media advertising, mostly from outside Ontario. The German market is particularly well known for demanding exceptionally high brightness kraft pulps, which is somewhat ironic since the German regulatory authorities prohibit the manufacture of kraft pulp in their country. In Germany, television advertising is not practised and the magazine industry is very large, with intensive competition in the advertising community. High brightness levels are frequently stated by the media to be a major contributor to bleach plant pollution discharges, but, as shown in the discussion below, the effect of product brightness on effluent characteristics is minor.

It is very difficult to put an economic value on these last few points of brightness. In principle, the marginal value of one brightness point would correspond to the amount by which a producer has to reduce the selling price of his product of 89 brightness to sell in competition with an otherwise identical pulp of 90 brightness. There are no references in the literature to this. One of the authors has experience in resolving such issues with customers which demonstrate that the cost of being slightly below the desired brightness levels, or marginally off specification in other ways. is generally reflected in negotiated reductions in selling price. These reductions are highly variable, and appear to be in the range of $15 to $50/tonne pulp. In cases where a product is shipped to a customer, and discovered to be off-grade on site, due to unforeseen brightness reversion or other problems, the costs of satisfying the customers requirements can be much higher, since they could include shipping the pulp elsewhere and replacing the unsatisfactory shipment. This uncertainty is the cause of some of the reluctance to change established and proven manufacturing processes on the part of management of some mills.

To summarize, brightness is a key criterion in determining the marketability of a pulp, but the authors are unable to provide the cost basis for an economic assessment of its significance relative to effluent discharge control costs since the effect on pulp selling prices is unpredictable.

Pulp strength

The **strength** of the pulp is naturally a key criterion of quality. There are several standard tests used, which determine the load to rupture a pulp specimen under various conditions of tension, tearing etc. Strength is a more pragmatic and less emotional criterion than brightness, and is a key factor in selling many of the softwood pulps manufactured in Canada, including Ontario.

Viscosity

Viscosity is a marketing problem for mills, since many customers are under the mistaken impression that viscosity is a useful measure of strength.

To control the bleaching process a property known as pulp **viscosity** is universally used. The objective is to determine the degree of polymerization of the pulp by one of the standard tests, (e.g. TAPPI 1988). This test is useful for control of the bleaching process because it can be performed relatively rapidly and simply in the mill. It provides a good prediction of the strength properties of the pulp for any one bleaching line whereas the above mentioned strength tests cannot be performed until some hours after the pulp has been bleached. The results of such strength tests are of limited value to an operator who must adjust the chemical dosages frequently.

Unfortunately, the widespread use of viscosity determination as a process control tool has caused considerable misunderstanding of the effect of new bleaching and pulping processes on pulp quality. This is because the **relationship of pulp strength (the characteristic the customer should be concerned about) to viscosity is not absolute, but depends on the bleaching process and chemicals used**. Specifically, oxygen delignified pulp has a lower viscosity than pulp bleached entirely by traditional chlorine based sequences, whereas its strength is equal according to many authors (Croon 1971, Jamieson 1973, Schleinkofer 1982 and 1983, Libergott 1985, Munro 1987, Tench 1987).

This change in the relationship of viscosity with strength holds true for extended delignification whether it takes place internally in the digester or externally with oxygen. As the lignin content is lowered the Kappa number goes down, the viscosity falls but the strength does not follow the viscosity trend. The strength levels are maintained with MCC delignification even at very low Kappa numbers as illustrated in Table 8. Based on this data it could be said that the commonly used viscosity tool is risky to apply below a Kappa number level of 15.

Table 8 Pulp strength after conventional and extended cooking at Longview Fibre

Kraft pulp for	Unbleached Kappa No. CP	Bleached pulp beater tests @ 300 CSF				
		Visc. factor g/m²	Burst length m	Breaking factor g/m²	Tear endurance	Fold
Regular soft	28	35	80	11,400	78	1440
Super soft	15	16	76	11,300	80	1520
Super duper soft	9	10	75	10,900	80	1220

The viscosity drop from 16 to 10 is close to 40% while the breaking length drop is less than 4%. Source Haas (1990)

3.7.3 Chlorine-based bleaching sequences

All kraft pulp bleached in Ontario is processed by conventional processes, but often with relatively high chlorine dioxide substitution or similar sequences[28]. This range of processes became established in the 1950s and has been the subject of extensive research into optimization, the sources of environmental contaminants, and potential mitigative measures. The current trend in Ontario and elsewhere is to further increase chlorine dioxide substitution.

Many North American kraft pulp mills, including some in Ontario, have modified their bleaching equipment to be able to operate with 100% substitution of chlorine with chlorine dioxide. It is increasingly common for those mills to operate for periods as long as several days to produce pulp grades based on 100% substitution, thus avoiding using any molecular chlorine, but few mills operate continuously in this mode. Operating costs are several dollars per tonne pulp higher than conventional bleaching operations. The reports of actual cost differences vary, and much of the relevant data is considered as being proprietary.

The efficiency of the pulp delignification and washing stages which precede the bleach plant can have as much impact on the bleach plant effluent characteristics as the bleaching process itself. Residual lignin that is not removed from the pulp by the washing system, will be discharged with the bleach plant effluent, usually in a chlorinated form which is normally even less environmentally desirable than the lignin and associated substances themselves. Effective brown stock washing is therefore a prerequisite to action in the bleach plant itself to minimize effluent discharges. Any analysis of data concerning such effluents must take account of the lignin content of the unbleached pulp.

Any process which reduces the lignin content of the pulp entering the bleach plant, as summarized in Table 6 on page 70, will reduce the consumption of molecular chlorine and chlorine based chemicals, with consequent reduction of organochlorine discharges.

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[28] *Eddy, Espanola is an exception to the extent that oxygen delignification is used to remove approximately half of the lignin separated from the fibres in their bleaching process, prior to chlorine based processing.*

3.7.4 Chemical requirements for bleaching

The quantities of chlorine and chlorine compounds required for bleaching vary widely, depending on wood species, extent of delignification in the pulping operation and the design of the bleach plant. Long retention in reaction towers, good washing between stages, modern process controls and good operating practices all contribute toward lower chlorine consumption. The converse is also true.

The term "chlorine equivalent" is widely used to define the "equivalent bleaching power" of the popular bleaching chemicals. It refers to a simple comparison of free electrons available to oxidize lignin in the bleaching reactions. Common values are:

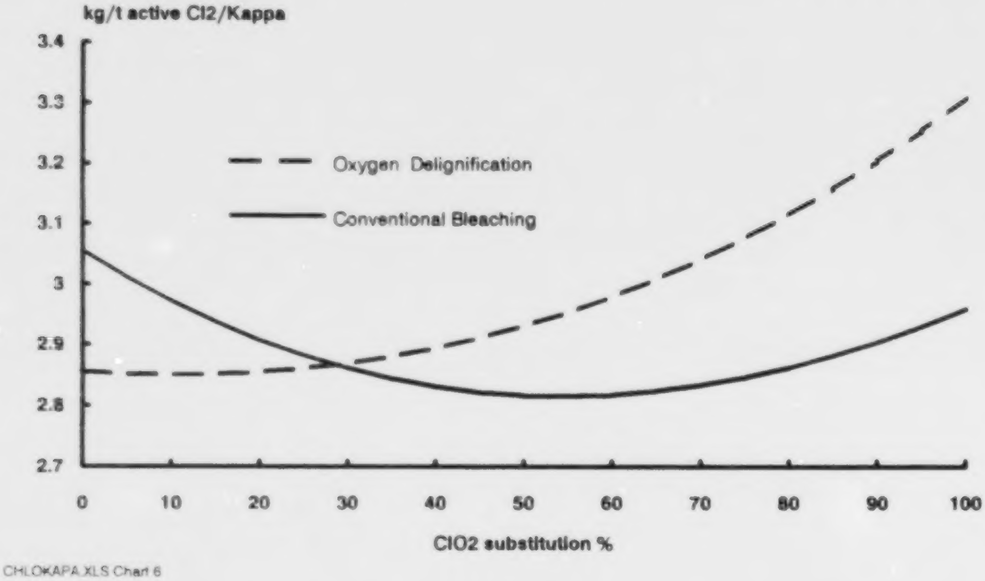
Chlorine = 1
Oxygen = 2
Hypochlorite = 2
Hydrogen Peroxide = 2
Chlorine Dioxide = 2.63
Ozone = 3

In practice, the actual values vary somewhat, but the above values are useful for rapid estimates. With the disappearance of chlorine from an increasing number of bleach plants, the term **"oxidizing equivalent"** is being used rather than "chlorine equivalent".

In conventional bleach plants, softwoods generally require about 100 kg chlorine equivalent tonne pulp to bleach to market quality, including attaining 90 ISO brightness. Some or even all of the chlorine can be replaced by chlorine dioxide. In practice the Ontario mills report using from 80 to 110 kg chlorine equivalent per tonne pulp. Those producing higher brightness market grades are at the upper end of the range.

Hardwoods generally require about 25% less chlorine equivalent than softwoods.

Where the pulp is delignified beyond conventional levels (about 30 Kappa for softwoods), the quantity of equivalent chlorine required drops roughly in proportion to the extent of delignification. However the ratio of chlorine required:incoming Kappa number is not constant. The authors have used the data presented in Figure 12 to estimate chlorine demand for various pulping modifications. These curves were calculated by Mannisto from data presented by Pryke (1989) and are accepted by several bleaching experts as providing a good estimate of relative bleach chemical demands.



Source: Mannisto 1991

Figure 12 Estimated chlorine demand for bleaching softwood pulps

Other chemicals used in bleaching include sodium hydroxide and sulphuric acid. They have no effect on organochlorine discharges, so are not discussed here.

3.7.5 Alkali/oxygen extraction

The use of relatively small quantities of oxygen in the conventional caustic extraction stage, as shown in Figure 11, has been shown to have some advantages in reducing the consumption of chlorine dioxide in later bleaching stages. This has a minor impact on effluent quality, but since it decreases the input of chlorine to the system, it reduces the discharge of chlorinated organic compounds by about 15%.

In this process variation, the gaseous oxygen is mixed with the pulp and sodium hydroxide immediately prior to the caustic extraction (E) stage of a conventional CEDED or D_CEDED (or similar) bleaching process. The gas is introduced near the bottom of the extraction tower, which is typically about 20 m high, where the hydrostatic pressure is about 200 kPa, and the oxygen reacts with pulp almost immediately (Nonni 1985, Massey 1984).

Almost all Canadian mills have installed permanent equipment for its application.

3.7.6 Effluent flow

All the water used in the bleaching process has to be heated to the operating temperature (30 to 75 deg C, depending on the stage), so that any decrease of water use normally decreases bleach plant steam consumption, and economies of a few dollars per tonne are common. Since bleach plant effluents are not normally used elsewhere in the mill, any decrease in water input to the bleaching process is normally accompanied by a corresponding decrease in effluent flow.

In the 1960s, bleach plant effluent flow was typically about 100 m^3/tonne pulp, but this has been decreased in many mills by various process modifications. Some mills are now discharging as little as 25 m^3/tonne from the bleach plant, and one claims occasional effluent flows under 15 m^3/tonne. The reductions in effluent flows have been accomplished primarily by countercurrent washing, which is the recycle of filtrate from one washing stage to one of the preceding stages. The concept is very simple, but there are a number of constraints on the extent to which filtrate reuse can be implemented, particularly in older mills, although solutions have been developed to solve many of the problems.

Corrosion is the most general problem encountered, since recycle raises the temperature in the process as well as the chloride concentrations. The pH may also be lowered, which tends to accelerate corrosion, but judicious selection of the filtrate recycle design can mitigate this to a large extent. Stainless steels with high molybdenum content, titanium, or plastics have been used in many recently installed bleach plants for virtually all wetted parts to minimize maintenance and to allow higher chloride concentrations. Chloride concentrations up to about 6000 mg/L are considered acceptable in some mills, which theoretically corresponds to effluent flows lower than 20 m^3/tonne, indicating that chloride concentration, in itself, is not yet an absolute limit on effluent recycle in bleach plants. Where titanium has been used for chlorination washers and other critical parts, it has been successful in reducing corrosion, and chloride concentration is no longer significant as a constraint on filtrate recycle, although the capital cost is substantial. The current trend to replacing chlorine with oxygen based bleaching and delignification agents generally leads to reduced flows as well.

There are a number of discussions in the literature concerning the potential of operating bleached kraft mills with little or no effluent including a report on the only attempt at building a full scale effluent free kraft mill in Thunder Bay, Ontario (EPS 1980). These indicate that **zero effluent will not be technically feasible in the near future but that considerable progress has been made. Nevertheless a substantial reduction in effluent flows is attainable using currently available technology. Refer to Chapter 6 on emerging technologies.**

3.7.7 Effluent BOD

The BOD of bleach plant effluent depends primarily on how much of the unbleached pulp must be extracted to attain the desired brightness. For typical softwood plants bleaching to a brightness of 90 ISO for market pulp grades, about 8% of the original pulp is extracted and discharged to the sewer. In the case of hardwood pulps, the shrinkage is normally a few percent lower. A common rule of thumb for estimating discharges from bleach plants is to assume that the BOD expressed as kg/tonne is 50% of the incoming Kappa number, provided that the incoming pulp is well washed.

The extended delignification technology has provided an opportunity to significantly reduce the dissolved solids load to the effluent treatment facilities. By lowering the Kappa number in the digester with MCC or MBC, the additional lignin removed enters the recovery cycle and is burned in the boiler. With oxygen delignification a further quantity of lignin can be removed and sent to the recovery boiler. The material removed by extended delignification (MCC, MBC, and oxygen delignification) would otherwise be removed in the bleach plant and become part of the BOD, COD, AOX, and other dissolved solids load that must be detoxified and discharged to the receiving waters. There is a limit to the removal of lignin and other wood components possible by extended delignification. This is determined by site specific conditions including the pulp grades that are manufactured.

If the pulp entering the bleach plant is not effectively washed, the residual black liquor will be removed by the bleaching equipment, substantially increasing the BOD apparently due to the bleach plant. The lignin in the residual black liquor will react with the molecular chlorine, consuming substantial quantities of it, increasing bleaching chemical cost and increasing the concentration of organochlorines in the effluent.

Assuming that the pulp is adequately washed, there remains a range of possible trade-offs between the degree of delignification attained in cooking and that in bleaching. Mills that cook the pulp to lower Kappa numbers (signifying lower residual lignin content) will have lower bleach plant BOD discharges. However, in practice the range of possible variations in Kappa number is limited, so that bleach plant effluent BOD is normally in the range of 15 to 20 kg/tonne pulp. In any one mill the decrease in bleach plant effluent BOD attainable by manipulation of the unbleached Kappa number is limited to a few kg BOD/tonne, except for the case where oxygen delignification is used, where BOD reductions in the order of 50% are common.

3.7.8 Organic substances in bleach plant effluents

Some environmental aspects of the mass balances for several widely used bleaching sequences are shown in Table 9. These were calculated by the authors for typical operating conditions for softwood pulps. In all cases, most of the fraction of the original wood that is separated from the pulp fibre in the digester is burned in the recovery boiler, with under 1% finding its way to the effluent system.

The first three columns are for conventional bleaching systems. For each tonne of semi-bleached pulp (82 or lower brightness), 52 kg of dissolved wood solids are discharged. For a pulp with a brightness of 85 to 87, 62 kg of dissolved solids leave the system while for fully bleached pulp (90 + brightness) 73 kg are discharged. These quantities of dissolved solids indicate the approximate quantities of the oxygen demanding components of the effluent, and will exert a BOD which is in the order of 20% of the mass flow, equivalent to a difference of about 4 kg BOD/tonne pulp between semi and fully bleached pulp. In mills with efficient biological treatment systems as envisioned in the alternative technology trains discussed in this report, the effect on treated effluent BOD discharges would be barely detectable, but would of course be obvious in mills without treatment.

Of the 73 kg of dissolved solids discharged during full bleached pulp runs, 54 kg or 74% are created in the initial stages of the bleach plant. By dropping the brightness to the mid 80s, the dissolved solids decrease to 63 kg or to about 86% of that resulting from fully bleached pulp. By implementing oxygen delignification, the solids load discharged to the effluent would be reduced to about 30 kg per tonne or about 58% of the load from standard bleaching. Similar reductions would occur for the other levels of brightness.

Table 9 Brightness of pulp and effluent discharges of various bleaching sequences

Bleach sequence	CdED	CdEDED	CdEDED	OCdEDED	OCdEDED
Brightness level (ISO)	<82	85-87	90+	90+	85-87
Wood to digester	2189	2212	2238	2189	2215
Unbleached pulp	952.4	962.6	973.0	973.7	963.5
Dissolved in oxygen delignification				26.3	26.0
Solids removed from pulp in bleaching					
CdED stages	52.4	52.7	53.9	30.1	29.0
ED stages (last two)	0.0	10.0	19.5	17.6	8.6
Organics to bleach effluent	52.4	62.7	73.4	47.7	37.6

Unless noted otherwise, units are expressed as OD kg/ADt bleached pulp. Refer to discussion in text on quantity of chlorinated substances in the organics discharged.

3.7.9 Toxicity

Kraft mill effluents high in resin acids are toxic to fish. High losses of black liquor solids in the pulping and recovery areas, are a major fraction of the total mill effluent toxicity.

Bleach plants are frequently mentioned in the literature as a major cause of toxicity in kraft mills. There is evidence that much of the toxicity attributed to bleach plants was caused by resin acids being carried over from the brown stock washing to the bleach plant, and subsequently being washed out in the E stage. Where the unbleached pulp is well washed, the bleach plant effluent is a less significant contributor to total mill effluent toxicity. Where oxygen delignification was installed upstream of a bleach plant, using 50% chlorine dioxide substitution, the whole mill effluent was shown to have lower chronic toxicity to fish than biologically treated effluent from a conventional bleach plant (Folke 1991).

A number of mills have modified the bleaching sequence to substitute some of the molecular chlorine with chlorine dioxide in the chlorination stage. The degree of substitution practiced varies from a few percent to 100%, with values around 10% common in the past. Many mills have recently installed equipment to increase substitution substantially in response to public and customer concerns and 100% substitution is becoming increasingly common. Increasing levels of chlorine dioxide substitution generally reduce bleach plant effluent toxicity, although the reported data on this are variable and occasionally contradictory.

3.7.10 Colour

Assuming that the brown stock washing and black liquor recovery systems are operating properly, with reasonably low losses of black liquor solids, the first E (caustic extraction) stage of the bleach plant is by far the most significant cause of colour in the mill effluent, as indicated in Table 10. The data therein are based on Rush and Shannon (1976), and are typical for the Canadian industry. The units used are APHA chloroplatinate units, so the kg/tonne represents an abstract quantity which is the best way of defining the total quantity of coloured material discharged.

Table 10 Sources of bleach plant effluent colour for traditional bleaching process

Stage	Softwood	Hardwood
C	50	26
E	226	78
D	11	6
E	6	4
D	1	1
TOTAL	294	115

Data are shown as kg/ADt pulp. This breakdown is typical for a traditional bleach plant. Most plants are generally similar, with substantially lower values for hardwood and/or any process modification that reduces the incoming Kappa number, such as oxygen delignification or extended cooking.

It is clear that the E-stage is the most significant source of bleach plant effluent colour, and that process modifications to prevent colour discharges at source must modify or eliminate this stream. External treatment processes for reducing effluent colour are usually based on segregation and treatment of this effluent.

A number of chlorine based bleaching sequences have been developed in research laboratories which decrease effluent colour, and to some extent toxicity and BOD (Sharpe 1975, Wong 1978, Reeve 1982, and Chan 1983). In most cases they involve some penalty in operating cost and/or pulp quality, but they have been judged more cost effective than external colour removal systems by several US mills. They are based on the use of sodium hypochlorite to replace some or all of the sodium hydroxide in the extraction stage, and usually use a high degree of chlorine dioxide substitution in the first stage of the bleaching process.

Where an oxygen delignification step is installed upstream of the bleach plant, the quantity of lignin entering the chlorination stage is, of course, reduced, with corresponding reduction in colour. In addition, the installation of such a process normally implies effective brown stock washing and a closed screen room. This will reduce colour discharges by up to a further 50%, depending on the original losses from the brown stock washers.

Several external effluent treatment techniques have been developed to decrease the colour in bleached kraft mill effluents (Rush and Shannon 1976). The authors are aware of only two that have remained in operation for more than a few years. One exception is a site-specific system at Skookumchuk, British Columbia which relies on the capacity of the local soil to absorb colour bodies. The other is at the Leaf River bleached kraft mill in Alabama, where chemical coagulation is reportedly used.

Current AOX reduction technology generally reduces colour substantially, but this has not been analysed in the report since colour is not on the Ontario Effluent Monitoring Priority Pollutants List (EMPPL).

3.7.11 Organochlorine compounds

Whenever molecular chlorine or chlorine compounds are used to bleach pulp, a wide variety of organochlorines are created. The majority of these substances are formed in the first chlorination stage of the bleach plant, and appear in both the chlorination stage and the subsequent caustic extraction filtrates (Refer to Figure 11 on page 73).

Dioxins and Furans

In 1985 the polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans (PCDD/PCDF), commonly referred to as dioxins, were unexpectedly detected by the US Environmental Protection Agency in the fish collected downstream from some pulp and paper mills (Amendola 1987). Although media attention has focussed on the 2,3,7,8 Tetrachloro dibenzo-p-dioxin and 2,3,7,8 Tetrachloro dibenzofuran, most of the scientific analyses determine the concentrations of several homologues of PCDD and PCDF. Refer to discussion commencing on page 133. These findings provided some of the first indications that pulp and paper mills employing a chlorine bleaching process might be a source of PCDD/PCDF. Other sources of PCDD/PCDFs are incinerator emissions (Swanson 1988) and PCP contaminated chips.

The PCDD/PCDFs are formed when unchlorinated precursors, i.e. DBD and DBF enter the bleach plant along with the pulp. These precursors, particularly DBF, were detected in some oil-based defoamers (Voss 1988). The use of these defoamers has been eliminated from all Ontario mills. The over-chlorination of organic material usually leads to the formation of PCDD/PCDFs. The major portion of these compounds is formed in the chlorination stage. The following operating conditions also contribute to formation of PCDD/PCDFs:

The pulp is not washed well prior to chlorination
High chlorine ratios are used
The chlorine and pulp are not mixed effectively
The chlorine dosages are not controlled well
The chlorine washer effluent is recycled
Chlorinated water is used in the bleach plant (Kringstad 1988).

Most mills in Ontario and elsewhere have modified their equipment and operating practices in accordance with the above list over the past few years to reduce the formation of PCDD/PCDFs.

Notice that all these conditions that are known to affect the formation of PCDD/PCDF, including the TCDD/TCDF, refer to the pre-bleaching processing and the first bleach stages. This conclusion is supported by the NCASI/EPA 23 mill study (Dallons 1990), Swanson (1988), and Kringstad (1988). The present authors are not aware of any evidence or chemical theory which contradicts this critical conclusion. It is well known that the brightness of the pulp produced is not related to these early bleaching stages, leading to the conclusion that the **brightness of the pulp produced has no relation to emissions of TCDD and TCDF.**

AOX

AOX is a widely used way of expressing the organochlorine content of an effluent or other sample. Up to about 7 kg AOX/ADt pulp are normally found in effluents from conventional softwood bleach plants. The Ontario mill AOX discharges ranged from approximately 1 to 6 kg/ADt during the 1990 effluent monitoring program.

Refer to page 126 for discussion on the prediction of AOX discharges from a complete bleach plant. AOX discharges can be reduced substantially as discussed in Chapter 5.

Histed (1989) and Lindstrom (1990) indicate that under 0.1 kg AOX per tonne pulp are discharged from the final three stages, regardless of the extent of chlorine dioxide substitution or whether the pulp is delignified with oxygen prior to bleaching.

3.7.12 Brightness targets and effluent characteristics

Since the characteristics of bleach plant effluents depend on the bleaching processes and quantities of the different chemicals used, it is important to understand the relationship between brightness and discharges of organochlorines.

Dioxins and furans

There is abundant evidence that 2,3,7,8 TCDD and 2,3,7,8 TCDF are formed primarily in the chlorination stage, and that the quantities formed depend primarily on the chlorine multiple and the presence of precursors. (Dallons 1990, Voss 1988, Rappe 1989, Swanson 1988, and Kringstad 1988). It is not uncommon to find 2,3,7,8 TCDD/F in the filtrates discharged from later bleaching stages, and in the finished pulp, but it appears that they are simply products of the chlorination stage, washed out by the subsequent bleaching processes.

The chlorination stage, together with the subsequent caustic extraction stage, is always used to remove the majority of the lignin in the pulp remaining after cooking and any oxygen delignification stage that may be installed. Refer to the typical kraft mill flowsheet in Figure 11 on page 73. The chlorination stage is labeled "C" and the first extraction stage is immediately to the right, labeled "E"[29]. Bleach plants operate to lower the Kappa number of the pulp leaving this first extraction (E_1) stage to a level where the pulp becomes bleachable. This "extracted Kappa number" is identical, regardless of the brightness of the final pulp to be produced. At this stage the pulp brightness is typically about 50 ISO.

To raise the pulp to the levels useful in an integrated mill (80-85 ISO) or to market quality (85-90 ISO), chlorine dioxide (D1), a second caustic extraction (E_2) and a second chlorine dioxide stage (D_2) are commonly used (shown as the D E D stages in Figure 11 and often known as the "final" bleaching stages). Many variations of the quasi-standard DED stages exist, including DND,

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[29] *All Ontario mills use at least some chlorine dioxide in the "C" stage, so it should strictly speaking be labeled "CD". However, it is common practice to simplify the description by calling it the "C" stage. Similarly, most mills now use oxidative extraction, which may be labeled "Eo".*

HDED, HD and simply D. The latter would be used where a slightly lower brightness pulp is required.

The quantity of bleaching chemicals used in the final bleaching stages will depend mostly on the quality of the equipment, operational skill, and the brightness of the pulp required, with about 3 to 5 kg chlorine dioxide per tonne pulp required to reach 80 ISO brightness and 6 to 12 kg/tonne required for a market pulp. Sodium hypochlorite was widely used instead of some of this latter chlorine dioxide in the past, but its use is declining rapidly due to pressures to reduce formation of chloroform and improve pulp quality.

Whatever the variation on these final bleaching stages, the total discharge of 2,3,7,8 TCDD and 2,3,7,8 TCDF with the pulp plus the effluent will be identical, because the unwanted substances are formed in the chlorination stage.

AOX discharges

As discussed on page 126 the quantity of AOX discharged in bleach plant effluents depends primarily on the quantity and type of chlorine based bleaching agents used in the chlorination stage.

Histed (1989) showed that the AOX discharge from softwood bleaching sequences processing pulps which had been subjected to conventional cooking, with and without oxygen delignification was concentrated in the initial DC and Eo_1 stages, and that in either case, under 0.1 kg AOX per tonne pulp was discharged from the $D_1E_2D_2$ stages. Boman (1991) presented data indicating that this was also the case for softwood pulp that had been cooked to very low Kappa (about 13) by the extended cooking technology discussed on page 160.

Although both the above mentioned authors described AOX discharge from the $D_1E_2D_2$ stages of the bleaching process as "under 0.1 kg/tonne pulp", examination of their data indicates that typical values were closer to 0.05 kg/tonne. After biological treatment, the contribution of AOX to the final mill effluent would be somewhat under 0.05 kg/tonne.

Consideration of the above mentioned mass balance for the dioxins and furans, and the latter findings by Histed and by Boman, raise the question as to whether a similar situation could apply to AOX, in that the latter stages of bleaching do not contribute to the total AOX discharged by the mill in the effluent and the pulp.

Histed (1989) presented a graph indicating that the decrease in lignin-bound chlorine in the pulp through the DED stages was greater than the measured organochlorine content of the filtrates discharged from these stages. This suggests that perhaps they do not generate any AOX, but rather that AOX from earlier bleaching stages is released from the pulp as the lignin is dissolved. It appears also that the $D_1E_2D_2$ stages reduce some of the AOX to chloride. This mass balance is not rigorous, since the analytical procedures for organochlorine were not identical for the pulp and filtrate, but was the only data the authors were able to uncover indicating the probable balance for AOX in the later bleaching stages.

There appears to have been relatively little research on the mass balance of AOX around individual stages of bleach plants, although the earliest work the authors are aware of was by Histed in the 1960s. At the time, Histed and his co-workers were investigating the causes of brightness reversion in bleached kraft pulps, and the current analytical procedures for AOX had not been developed.

These data led the authors to conclude that reducing the target brightness of bleached kraft pulp from 90 ISO to 80, would reduce mill effluent AOX discharges by under 0.05 kg/tonne pulp. There is evidence that bleaching to the lower brightness targets could cause a net increase of organochlorine discharges by transferring the AOX load to the paper product.

The authors concluded that **reducing brightness targets is not an environmentally sound way of controlling AOX in the effluents from bleached kraft mills, and may be marginally detrimental to the environment**[30]. It would seem appropriate to confirm that Histed's data are applicable to all conditions, since they may have a significant impact on MOE regulatory development. It would be desirable to undertake a detailed mass balance for AOX on all stages of a typical kraft bleach plant to establish the true environmental significance of the later bleaching stages.

Closing comment on kraft bleaching effluents

Critics of the pulp industry's environmental protection practices frequently suggest that it would be environmentally desirable to abandon bleaching kraft pulp to the level of 90 ISO which is currently accepted as being market quality. They suggest that if kraft pulp was not bleached beyond, 80, or 82 brightness, that discharges of organochlorines would be reduced.

The foregoing discussions show that the major fraction of the environmental load from bleaching is developed in the production of low brightness pulps. Achieving high brightness levels by further bleaching of these pulps is accompanied by the creation of a lesser quantity of additional dissolved solids than produced by the first bleaching step, probably no measurable amounts of TCDD and TCDF, and the transfer of AOX from the pulp to the effluent. Although the additional environmental impact of high brightness is relatively minor, it is commercially very expensive to produce. One must assume that market pulp producers would manufacture a lower brightness standard if customers would accept it.

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[30] *These comments refer to production of pulp for to-day's mills and the currently proven bleaching processes. It may well be environmentally desirable to lower brightness targets for other emerging or future bleaching processes.*

3.8 Sources of Chemicals

SUMMARY Molecular chlorine and sodium hydroxide are produced in stoichiometrically equivalent amounts from the electrolysis of sodium chloride. Sodium chlorate is manufactured without sodium hydroxide by electrolysis of sodium chloride. Chlorine dioxide is always produced on-site - in the past by a variety of processes. The current trend is to convert to the R8/SVP-Lite processes in which the sodium chlorate is reduced by methanol with lesser by-products. Oxygen is obtained from distillation of air at a central plant and trucked to the mill or manufactured on site. Ozone is manufactured on-site by electricity using oxygen as a feed stock. Hydrogen peroxide is produced at central plants. Enzymes are produced at a central plant using selected microorganisms to digest a nutrient rich substrate, then dissolving the organisms grown and isolating the enzyme from the solute.

3.8.1 Molecular chlorine and sodium hydroxide

Molecular chlorine and sodium hydroxide (caustic) are produced by electrolysis of salt (sodium chloride) in several centralized plants in Canada and shipped to the mills. An essential factor of the production process is that caustic and chlorine are provided in the ratio of 1.13 parts caustic to 1 part molecular chlorine. The manufacturers prefer to sell to pulp mills in this "Electro-chemical Unit" (ECU) ratio. Historically, the chemical balance in Ontario mills has allowed them to purchase in the desired ECU balance. However, the recent trend toward partial or complete elimination of molecular chlorine has upset this balance, leading to declining prices for molecular chlorine and increasing prices for caustic. If molecular chlorine use were eliminated completely, then alternative production systems for caustic would have to be installed by the chemical suppliers. The technology is known and proven, and is being installed on an industrial scale. The pulp and paper industry is a major but not exclusive purchaser of these chemicals, so that prediction of the effects of changes in pulping and bleaching practices on prices and availability is complicated by the need to predict many interrelated industrial trends.

Molecular chlorine is shipped as a liquid, under pressure, normally by rail. Caustic is shipped by rail or truck, normally as a 50% or 73% solution in water.

3.8.2 Sodium chlorate

Sodium chlorate is an essential feed chemical to all chlorine dioxide manufacturing systems. It is manufactured electrolytically, normally at a central plant, but perhaps at a mill site. The pulp and paper industry is the only significant industrial user. McCubbin (1990) indicated that there would be sufficient sodium chlorate available for the expected increase in demand as mills install increased chlorine dioxide generating capacity. Sodium chloride (salt) is the feedstock.

3.8.3 Oxygen

Where consumption is under about 10 tonne/day, such as for oxygen assisted extraction in bleach plants, oxygen is usually manufactured in a central plant and trucked to mills in liquid form, under pressure. For oxygen delignification, or oxygen based activated sludge systems, oxygen is normally purchased from a dedicated "over the fence" supplier. Oxygen manufacture requires only air and electrical energy as feedstock.

3.8.4 Ozone

Ozone has been manufactured electrolytically at the point of use for many years, primarily for the disinfection of drinking waters, on a scale comparable to the possible requirements for ozone delignification. Oxygen is the normal feedstock.

3.8.5 Hydrogen peroxide

Hydrogen peroxide is manufactured in central plants and shipped to mills, most commonly by truck. Most of the hydrogen peroxide used today is produced by the anthraquinone process. This is a cyclic process wherein a working solution of alkyl anthraquinone (RAQ) is sequentially hydrogenated, oxidized, subjected to extraction, and then recycled back to the hydrogenation step.

Hydrogen peroxide solutions are clear, colourless and water-like in appearance. Most hydrogen peroxide solutions are stabilized with tin and phosphate compounds, and some may also contain a nitrate salt to inhibit the tendency of any chloride ions to corrode aluminium storage equipment.

3.8.6 Chlorine dioxide manufacture

Chlorine dioxide was introduced to the pulp and paper industry in 1946. It is always manufactured on the kraft mill site, since it is impractical to transport significant quantities. While the principal objective of manufacturing chlorine dioxide is to produce a bleaching chemical, the chlorine dioxide plant is inextricably linked with the pulping/recovery process, since most of the practical processes produce significant quantities of by-product sulfur and sodium. If these chemicals are disposed of to a sewer, then the loss of chemical value adds substantially to the mill operating cost, and in most cases the acids must be neutralized with lime, creating a suspended solids disposal problem.

The chlorine dioxide processes in Ontario mills are the Mathieson, Solvay, R3, R7, R5, SVP-LITE, and R8 processes. In the early days, mills consumed all the sulphur by-products from chlorine dioxide manufacture due to the traditionally high chemical losses from the pulping cycle. However, increased attention to operating costs and environmental pressures have reduced pulping chemical losses substantially over the past 35 years, and rendered many chlorine dioxide processes uneconomical, since there is no demand for the by-products.

The Mathieson Process (Woodside 1953) uses sulphur dioxide as a reducing agent for the chlorate:

$$SO_2 + 2NaClO_3 + H_2SO_4 \longrightarrow 2ClO_2 + 2NaHSO_4 \qquad (1)$$

The Solvay Process (Schuber 1953) uses methanol as its reducing agent:

$$CH_3OH + 2NaClO_3 + H_2SO_4 \longrightarrow 2ClO_2 + HCHO + Na_2SO_4 + 2H_2O \qquad (2)$$

The stoichiometry of all the commercial processes can be satisfied as follows (Atkinson 1981):

$$2HClO_3 + 2HCl \longrightarrow 2ClO_2 + Cl_2 + 2H_2O \qquad (3)$$

The $HClO_3$ is fed to the generator as $NaClO_3$ and the acid that is required to provide the H^+ is either hydrochloric or sulphuric which produces sodium chloride or a form of sulphate.

The Solvay and Mathieson processes are based on reactors which contain a liquor of 30 to 40% H_2SO_4, chlorate, chloride and sodium. The reactors are agitated with air, which also strips the chlorine dioxide from the liquor, dilutes it to 10 to 12% and carries it safely to an absorption tower where it is contacted with 5 to 10 deg C chilled water to form a solution. It is then stored as an 8 to 10 g/L solution of chlorine dioxide in vented storage tanks.

The Rx[31]/SVP (McGilvery 1975) processes can be described by the equations (4) and (5):

$$NaClO_3 + NaCl + H_2SO_4 \longrightarrow ClO_2 + 1/2Cl_2 + Na_2SO_4 + H_2O \quad (4)$$

$$NaClO_3 + 5NaCl + 3H_2SO_4 \longrightarrow 3Cl_2 + 3Na_2SO_4 + 3H_2O \quad (5)$$

The R8/SVP-LITE (or R8/SVP-MeOH) version of this process, which is being used increasingly, is shown in Figure 13, and can be described by equations (6) and (7).

$$6NaClO_3 + CH_3OH + 4H_2SO_4 \longrightarrow 6ClO_2 + CO_2 + 2Na_3H(SO_4)_2 + 5H_2O \quad (6)$$

$$12NaClO_3 + 3CH_3OH + 8H_2SO_4 \longrightarrow 12ClO_2 + 3HCOOH + 4Na_3H(SO_4)_2 + 9H_2O \quad (7)$$

There are commercially competitive versions of this process, which differ to some extent, and mills may chose one over the other for various reasons, including price. However these differences are unimportant in the context of this report.

The Rx/SVP processes operate at approximately atmospheric pressure, at high acidity (450 to 500 g/L). However, the reactions take place at a lower acid normality (147 to 196 g/L), higher temperature (70 to 80 deg C), and a lower pressure (165 to 210 mm Hg Absolute) than the other processes. Steam is the stripping medium and the diluent for the ClO_2 produced. A heat exchanger provides the heat to evaporate water and crystallize the sodium sulphate which is filtered off and sent to the kraft pulping chemical recovery system. The unused acid plus residual chlorate and chloride are returned to the generator. The current trend toward replacing most or all of the chlorine used in bleaching with chlorine dioxide, along with the tendency to reduce chemical losses in the pulping cycle, results in more by-product sodium sulphate being produced than the pulping operation requires, so the excess would normally be discharged to sewer.

R8 and SVP-LITE processes are chemically similar, but are offered by competing suppliers. The R8/SVP-Methanol process reactions are similar to the Solvay process (Schuber 1953). The reaction is carried out at high acidities (294 to 441 g/L). **Very little by-product chlorine is produced.** The by-product sodium sesquisulphate must be neutralized with caustic before its addition to the recovery system.

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[31] *Rx refers to a family of related chlorine dioxide production processes R3 to R7.*

A more detailed review of these processes has been published by Owen (1990).

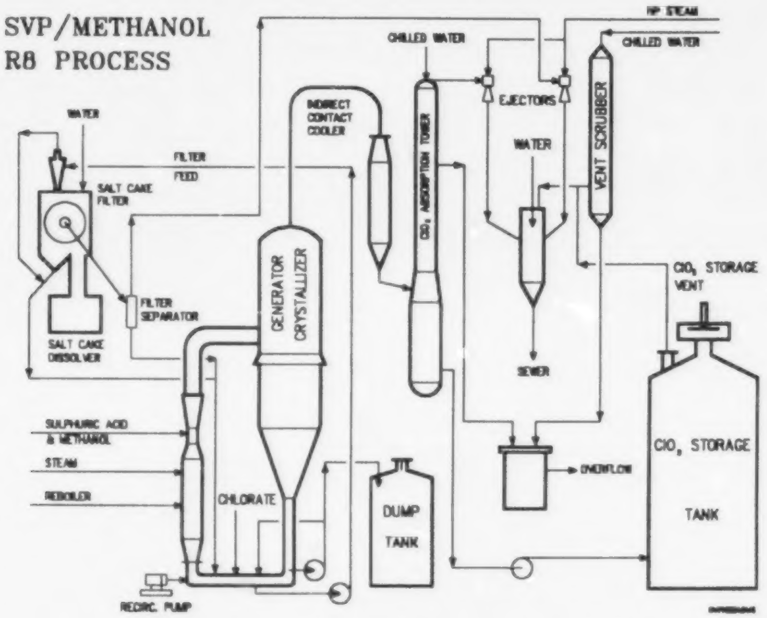
SVP/METHANOL
R8 PROCESS
HP STEAM
CHILLED WATER
CHILLED WATER
EJECTORS
VENT SCRUBBER
ClO_2 ABSORPTION TOWER
INDIRECT CONTACT COOLER
WATER
FILTER
FEED
SALT CAKE FILTER
WATER
GENERATOR CRYSTALLIZER
ClO_2 STORAGE VENT
FILTER SEPARATOR
SALT CAKE DISSOLVER
SEWER
SULPHURIC ACID & METHANOL
STEAM
REBOILER
CHLORATE
DUMP TANK
OVERFLOW
ClO_2 STORAGE TANK
RECIRC. PUMP

Figure 13 R8/SVP-MeOH process flowsheet

Chemical balances for the various chlorine dioxide production processes are shown in Table 11.

Table 11 Chemical balance for chlorine dioxide manufacturing processes used in Ontario

Chemical	Mathieson	R3	R5	R8	SVP/Methanol
Sodium chlorate	1.90	1.66	1.74	1.66	1.68
Sodium Chloride	0.19	0.96		0.03	0.03
SO_2	0.78				
Methanol				0.14	0.15
HCl			1.27		
H_2SO_4	1.47	1.60		1.05	1.06
NaOH	1.19	0.00		0.08	0.20
$Ca(OH)_2$	0.52				
By-products					
Chloride			0.95		
Chlorine		0.66	0.70	0.04	0.05
Salt cake	0.74	2.2		1.15	1.16
Eff. Acid	1.46			0.11	0.24

All data expressed as kg/kg chlorine dioxide produced
Salt cake make-up utilization
Caustic soda used as pulping chemical make-up at 35 kg/tonne

The extent to which credit can be taken for the by-product sodium and sulphur from each process has a considerable effect on the operating costs. The table shows quantities of the various chemicals involved, all per tonne chlorine dioxide produced.

The by-products are a mixture of sulphuric acid and sodium sulphate in most cases, so that any excess must be neutralized before being discharged to the sewer. Appropriate amounts of lime have been allowed in the cost estimates in this report.

A review of the systems installed in Ontario indicates that mills with R3 and similar processes can convert relatively easily to R8/SVP-LITE processes or stay with their existing process in order to accommodate the pulping/bleaching technology changes. The associated costs were estimated mill by mill and are included in the cost estimates discussed in Chapter 8.

Chlorine dioxide is manufactured on site at the pulp mill. In the Ontario mills covered in this report, the logical way of expanding chlorine dioxide capacity to satisfy the demands of the alternative technology trains discussed, is to convert the existing R8/SVP processes to R8/SVP-Lite. James River at Marathon has already commissioned an R8 generator, and Boise Cascade at Fort Frances has almost completed construction of an R8 generator. Malette at Smooth Rock Falls have already purchased a new SVP process generator capable of supplying sufficient chlorine dioxide for all the process alternates discussed in this report.

Table 12 Chlorine dioxide generation in Ontario

Company	Town	Status 1991
Boise Cascade Canada Ltd.	Fort Frances	30 t/d R8 start-up 1991
Canadian Pacific Forest Products Ltd.	Dryden	Can expand to R8/SVP-Lite
Canadian Pacific Forest Products Ltd.	Thunder Bay	Can expand to R8/SVP-Lite
Domtar Inc., Fine Papers Div.	Cornwall	Have capacity
Domtar Inc., Containerboard Division	Red Rock	New system reqd, see below
E.B. Eddy Forest Products Ltd.	Espanola	Can expand to R8/SVP-Lite
James River-Marathon Ltd.	Marathon	Added R8 recently
Kimberly-Clark Canada Inc.	Terrace Bay	Can expand to R8/SVP-Lite
Malette Kraft Pulp and Paper Co.	Smooth Rock Falls	New SVP-Lite under construction

In this table "can expand" implies that the system can be expanded to manufacture sufficient chlorine dioxide to operate the bleach plant at April 1991 production rates at 100% substitution in the first bleaching stage.

The two exceptions are the Domtar mills at Cornwall and Red Rock. The Domtar (Cornwall) mill has sufficient capacity to produce the necessary chlorine dioxide, although provisions for disposal of the additional waste acid from the chlorine dioxide generators will be required. Each additional tonne of chlorine dioxide will cause the discharge of 1.7 tonnes of sulphuric acid. This will be neutralised with calcium hydroxide, creating 2.4 tonnes of calcium sulphate which would be disposed of to landfill.

At the Domtar (Red Rock) mill, the quantity of chlorine dioxide required for train K1 on page 243 is unusually small, so the cost estimates are based on installation of a generator based on reacting sodium chlorite with molecular chlorine, similar to the chlorine dioxide generators used in many potable water treatment systems in municipalities. For the alternatives at Domtar (Red Rock) which require larger quantities of chlorine dioxide, the cost estimates assume that a small Mathieson process generator would be installed.

3.8.7 Enzymes

Enzymes are manufactured from microbiological cultures grown under controlled conditions in closed tanks. After digestion the culture is isolated, the cells are broken and the enzyme of interest is isolated. Proteolytic enzymes have been used in washing powder for decades to remove protein spots from cloth. Today, enzymes are being developed that may benefit the pulp and paper industry and some of them may improve the characteristics of pulp and paper industry effluents. One such example is xylenese (e.g. Pulpzyme from Novo Nordisk), an enzyme that can break the bonds between cellulose and lignin, facilitating delignification prior to bleaching, as a supplement, or perhaps alternative, to oxygen delignification. Refer also to Appendix G.

3.9 Recovery of Pulping Chemicals

SUMMARY The spent kraft pulping liquor removed from the pulp in the washing stages contains virtually all the original cooking chemicals and organic material removed from the wood. The quantity of total dissolved material depends principally on the pulping yield and is typically 1500 to 1800 kg/tonne for kraft pulp. All kraft mills in Ontario have chemical recovery operations, using the technology described in this section. Typically 96% to 99.5% of the spent liquor is recovered, and the rest becomes part of the mill effluent. The efficiency and reliability of the chemical recovery system has a major impact on all effluent parameters except those related to chlorinated organics.

3.9.1 Process description

The fundamental recovery process cycle in which the cooking chemicals are regenerated and the organic residues burned to produce energy for process and power is shown in Figure 8 on page 61 and Figure 11 on page 73.

The weak black liquor removed from the pulp by the brown stock washers is concentrated in a steam heated multiple effect evaporator to about 50% dry solids. This liquor is further concentrated to about 65% to 80% solids concentration either by direct contact with recovery furnace flue gas or indirectly in a forced circulation steam heated evaporator, generally known as a concentrator.

The strong black liquor is then burned in a recovery furnace. The organic matter burns, providing heat for steam generation, while the sodium/sulphur salts accumulate in the hearth of the furnace as a molten smelt. At the high temperatures and controlled conditions employed, the Na_2SO_4 added to the black liquor as make-up for sodium and sulphur losses is reduced to Na_2S as follows:

$$Na_2SO_4 + 2C \xrightarrow{\text{840 deg C}} Na_2S + 2CO_2$$

The molten smelt, composed mainly of Na_2S, Na_2CO_3 and some unconverted Na_2SO_4, flows by gravity from the furnace and is mixed with weak wash, the filtrate from lime mud washing, in the dissolving tanks. The greenish colour of chromium from chrome ore used to form the furnace bed, is imparted to the water mixture and thus it is universally referred to as green liquor.

The green liquor is pumped to a green liquor clarifier where carbonaceous ash residues, and other impurities are removed by sedimentation. The settled residue, known as green liquor dregs, or simply dregs, is washed to remove soluble sodium salts. The dissolved salts are returned to the system while the dregs are either hauled away for landfill or discharged to the sewer. Typically about 0.5 kg dregs are generated per tonne pulp.

The clarified green liquor is then routed to the causticizing system where calcium hydroxide is added, in the slaker, to convert the sodium carbonate to sodium hydroxide according to the reaction below:

$$Ca(OH)_2 + Na_2CO_3 \longrightarrow 2NaOH + CaCO_3$$

The reaction, which is rather slow, begins in the slaker and is completed in the causticizers, which are a series of agitated tanks immediately downstream of the slaker. The calcium carbonate formed from the reaction is quite insoluble and is settled out of solution in the white liquor clarifier. The clarified solution which overflows contains the two major active cooking chemicals, Na_2S and NaOH. This liquor is called white liquor and is ready for re-use in the digester.

The calcium carbonate removed from the white liquor clarifier is pumped to a lime mud filter where it is thickened and washed to recover sodium salts.

The thickened $CaCO_3$ is then calcined in a direct fired lime kiln, which converts it to calcium oxide as follows.

$$CaCO_3 + \text{heat} \longrightarrow CaO + CO_2$$

The CaO produced is recovered and used in the slaker.

The only solid wastes are the slakers grits which are non-reactive lime and inert mineral matter and the green liquor dregs consisting of carbon, ash and some sodium. This material carries many trace metals in the form of hydroxides or carbonates. This exit from the process will assume greater importance as mills approach zero process effluent.

The principal organic discharge in the chemical recovery system is the evaporator condensate, discussed below.

3.9.2 Evaporators

The weak black liquor is delivered to the chemical recovery department at a concentration of about 14 to 18% solids, and this concentration must be raised substantially by evaporation before it can be fed to the recovery furnace. Specially designed vertical shell and tube heat exchangers called evaporators are normally used for this evaporation process, arranged generally as shown in Figure 11.

Volatile organic compounds, principally methanol, condense in the shells of the surface condenser and the evaporators, and constitute a major BOD source. There is a discrete condensate stream from each of the several evaporator bodies, but the BOD distribution is very uneven. It is normal practice in the more modern mills to segregate the condensate streams to facilitate reuse. All the condensate is hot, and the less contaminated streams are suitable for use in the recausticizing and pulp washing departments.

The condensates are also contaminated with small quantities of black liquor carried over from the vapor heads of the evaporators. The designer's objective is to minimize this carryover, and in well designed adequately sized units, it is usually negligible. However, multiple effect evaporators are not easy to operate, particularly if they are overloaded or poorly instrumented, and liquor carry over is a frequent problem. Several kg BOD/tonne pulp can be transferred to the condensates by this carry over, and will pass through any condensate stripping system. More seriously, carry over can cause foam generation in a condensate stripper, and prevent its operation so that both the volatile BOD from the true condensates and the BOD of the black liquor, which is carried over, will be added to the mill effluent.

Since the environmental aspects of evaporator condensates became important in the 1970s, considerable development has taken place in the design of systems. A modern evaporator running at its design capacity can operate with only a few percent of the carry over of black liquor of older or overloaded systems. Current evaporator design criteria require a maximum of 1 gram sodium carry over/tonne condensate.

3.9.3 Evaporator and digester condensates

Contaminated condensates from the evaporators and the digesters are similar and are usually treated together, if at all. Figure 11 shows the source of the evaporator condensates in mills with batch digesters. The digester condensates are recovered from the vent of the digester blowing system which is located between the digester and the brown stock washers, but is not shown on the drawing due to lack of space. The source of digester condensates in a kraft mill equipped with a continuous digester are shown in Figure 32 shown on page 168.

These condensates contain a total of 8 to 15 kg BOD/tonne pulp. The BOD is caused by alcohols, ketones, terpenes, phenolics, resin and fatty acids, and the total reduced sulphur (TRS) compounds. Methanol is the most significant factor in the BOD load. Most of the organics are low molecular weight substances which are readily converted to water, carbon dioxide and other harmless compounds in a biological treatment system or the receiving waters.

Reported 96-hour LC_{50}s for contaminated condensates range from 0.04% to 17%, using fish as the test organism. Many of the contaminated condensate's components, such as the TRS compounds, and resin and fatty acids, are lethal at levels well below their concentration in contaminated condensates. The TRS compounds appear to be the dominant factor in contaminated condensate toxicity, but these are removed very effectively in biological treatment systems.

Contaminated condensates contain about 0.3 kg TRS (as S) per tonne pulp. Since some of the TRS compounds in the condensates are stripped from aerated lagoons by the process of aeration, sewered contaminated condensates can represent a significant source of odour from a biological treatment system.

Refer also to Appendix G for discussion of controlling odour and reducing BOD by condensate stripping.

3.9.4 Soap recovery

Soap skimming has long been a part of the kraft process but in recent years has become more important. A major reason for this is that resin acids contained in the soaps are one of the major toxic components in pulping effluents and also have an adverse effect on biological waste treatment systems. Soap skimmings consist largely of the resin acids and fatty acids present in the original wood which on pulping become ionized in the alkaline liquor, forming their sodium salts. In the dilute spent cooking liquor these salts remain soluble, but during evaporation they "salt out". This usually occurs at a black liquor solids concentration of 25% to 35%. This material is termed soap and can be removed by a rotating paddle at the surface of the liquor in a skimming tank. Where maximum soap removal is desired, the skimmer is normally located part way along the evaporator chain, where the black liquor concentration is around 30%.

Approximately 80 kg soap is formed per tonne of kraft pulp, typically containing 40% resin acids and 30% fatty acids. The BOD of soap approaches 100,000 mg/L, and its **LC_{50} for fish has been measured as 6 mg/L, i.e. moderately toxic**, so it is obvious that soap will have a significant effect on effluent quality if it is discharged to the sewer.

An adequate retention time in the tank (1.5 to 2.5 hours) permits the soap to float to the top. The skimmed soap may be converted to tall oil on-site or sold to an external tall oil plant. Alternatively it can be burned in the recovery furnace, effectively destroying it and recovering the heat and chemical value.

Since the soap can represent up to 10% of the total heat load on the recovery boiler, there is an opportunity to reduce the load on the latter by burning the soap elsewhere. It is fairly common practice to ship soap to other mills for conversion to tall oil with incineration of the residue. Recently some mills have investigated burning the soap in the hog fuel boiler, although there is no published literature on actual operations.

If there is no soap skimming equipment installed, there is a tendency for layers of soap to form on top of the strong black liquor storage tanks where some of this overflows to the sewer. Some mills with lower soap content liquor can effectively control soap losses simply by intermittently pumping off this layer and incinerating it. If there are no specific measures taken to avoid soap discharge to the sewer, then it will raise the toxicity of the mill effluent. A spill can be disastrous, and in one case there was a twenty-minute overflow which caused fish mortality over 45 km of river.

3.9.5 White liquor production

The molten smelt which flows from the smelt bed in a recovery furnace is composed mainly of sodium carbonate and sodium sulphide. This smelt drops through steam shatter sprays into a dissolving tank where it is dissolved to form green liquor, which is then causticized by mixing lime and water in a slaker. The reaction in the slaker takes place at around 100 deg C.

The mixture of calcium carbonate, sodium sulphide, sodium hydroxide and water produced by the causticizer is routed to the white liquor clarifier where the calcium carbonate settles out. The clarifier product is white liquor, which is the principal chemical ingredient in the cooking liquor required in kraft pulping as described on page 60.

The settled mud is washed by dilution then rethickened in another clarifier known as the lime mud washer, and then thickened to about 70% consistency in a vacuum filter and re-calcined to quick lime, CaO, in the lime kiln. A few mills use fluidized bed calciners instead of lime kilns.

Virtually all mills with oxygen delignification systems use a portion of the white liquor to supply the necessary alkali required in the oxygen reactor. White liquor contains about 25% sodium sulphide (Na_2S), and the latter must be oxidized by contact with air or elemental oxygen, as shown in Figure 32 on page 168.

3.9.6 Recovery cycle effluents

Theoretically, the only effluents from the kraft recovery areas would be evaporator condensates, green liquor dregs, and slaker grits as discussed above. However, there are a number of intermittent discharges due to spills of black liquor which can be up to 20 kg/BOD per tonne pulp. Good design and operating practices will reduce these spills to a few kg/tonne, and a spill control system, as discussed on page 189, is necessary to achieve a high level of environmental protection.

3.10 Recovery Boiler Capacity

SUMMARY The capacity of the mill's recovery boiler is often a limiting factor in attaining a high level of environmental protection. It is always technically feasible to reduce pulp production to release whatever recovery boiler capacity is required for environmental protection purposes, but this imposes a severe economic penalty. Approximately one-third of the kraft mills in Ontario are presently operating with recovery boilers at their maximum capacity. Replacement of an existing boiler would be expensive for those mills, but there are a number of potential technical solutions which are discussed in this section.

Oxygen delignification, extended cooking, and improved brown stock washing/screening can produce up to 12% additional black liquor solids in a mill which currently has relatively high losses of black liquor solids to the sewer. Where the mill already has good washing (soda losses under 10 kg Na_2SO_4 per tonne pulp), the additional recovery boiler load would be about half the above value. Refer to the sections of the report discussing these process modifications.

The operation and design of the recovery boiler are very important in the regulation of atmospheric emissions, and adequate recovery boiler capacity is essential if aqueous effluent discharge is to be minimized. Historically, recovery boilers have been rather undersized relative to the production capacity of the other processes in many North American mills.

Ideally, all organic material removed from the wood in the process of producing bleached kraft pulp would be incinerated in the recovery boiler. This is impractical in the case of organic material containing chlorine, since the chlorides produced will accumulate in the recovery cycle, causing severe corrosion and will eventually prevent its operation.

Modern practice is to design the recovery boiler to burn all the organic material and recovered chemicals produced from the cooking and brown stock washing processes in the mill. Where delignification is extended by oxygen bleaching, special cooking procedures or other techniques, an additional quantity of organic material is produced, which it is environmentally desirable to burn along with the conventionally produced black liquor.

All mills practising any form of extended delignification that the authors are aware of currently burn the additional black liquor produced. This material may lead to a reduction in the quantity of pulp that can be produced, so the issue of the capacity of the recovery system to process all the black liquor produced is critical in a mill attempting to minimize the discharge of aqueous pollutants. However, **it is possible to profit from the ability of extended delignification to reduce the discharges of organochlorines without burning any of the additional liquor**. The mill would simply be discharging the same amount of BOD and non-chlorinated organics as before installing the extended delignification system. A more probable scenario would be for a mill to burn a portion of the additional liquor, up to the capacity of the existing recovery boiler(s).

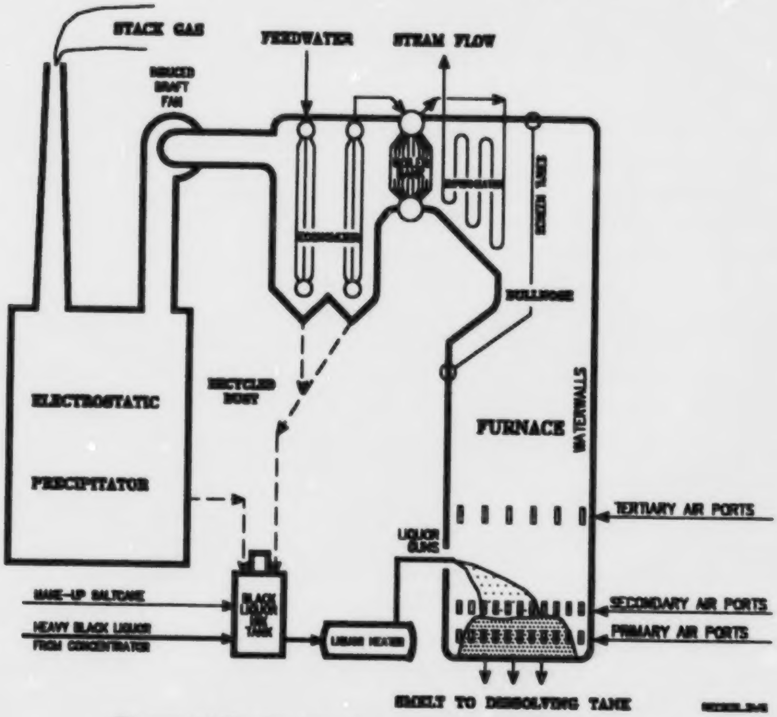
STACK GAS
INDUCED DRAFT FAN
FEEDWATER
STEAM FLOW
BULLNOSE
RECYCLED DUST
ELECTROSTATIC
PRECIPITATOR
FURNACE
WATERWALLS
TERTIARY AIR PORTS
LIQUOR GUNS
MAKE-UP SALTCAKE
HEAVY BLACK LIQUOR FROM CONCENTRATOR
BLACK LIQUOR MIX TANK
LIQUOR HEATER
SECONDARY AIR PORTS
PRIMARY AIR PORTS
SMELT TO DISSOLVING TANK

Figure 14 Typical modern recovery boiler system

3.10.1 Defining capacity

There is no universally accepted definition for recovery boiler capacity. For this report, it is defined as the **maximum quantity of black liquor solids that the boiler can burn, safely, reliably and without emission of excessive quantities of Total Reduced Sulphur (TRS) gases**. The latter cause the traditional disagreeable kraft mill odour. Boiler capacity is normally specified by the boiler manufacturer in terms of the feed of liquor solids per day, and this value is calculated by considering a number of aspects, including the heat release rate in the furnace[32], gas flows, rate of steam generation and the capability to reduce sodium sulphate in the feed liquor to sodium sulphide. Chamberlain (1981) and McCubbin (1990) discuss practical recovery boiler capacities.

A detailed technical study is required to assess the real capacity of any recovery boiler. In most cases, the key parameter is the total calorific value of the black liquor solids fed to the boiler, since this in turn determines the quantity of air required to achieve satisfactory combustion, which in turn determines the flue gas flow and temperature. This is significant in the context of this report, since there are several ways of reducing the calorific value of the liquor fed to the boiler. These can be used in practice to solve the problem of increased production of black liquor solids which accompanies the introduction of processes to improve effluent quality.

Overloaded boilers usually have to shut down frequently (several times per year) to water wash accumulated saltcake and related material from the boiler bank (Refer to Figure 14).

Personnel safety is an especially important issue with respect to recovery boilers. Experience has demonstrated that kraft mill recovery boilers are much more likely to explode than most other boilers, and many have done so, frequently with fatal consequences. Recovery boiler technology, including the safety aspects, has improved steadily over the past twenty years. **Any modifications of the recovery boilers to increase their capacity to burn black liquor must be designed to maintain a high level of safety for the operating personnel.** Some potential modifications intended to increase recovery boiler capacity, such as increasing the consistency of the feed liquor, inherently enhance safety.

3.10.2 Upgrading existing boilers

In practice, the recovery boiler itself is usually the most critical element in the chemical recovery system. A mill that wishes to modify the production process to improve effluent quality by recover and incineration of organic material, can be faced with installing a new recovery boiler. Technically, this is always feasible, since the technology is well demonstrated and developed, but the capital cost is generally in the 50 to 100 million dollar range, so that economic constraints are significant, and alternatives have to be considered, including reducing the load on the boiler.

There are several ways of increasing recovery boiler capacity by 5 to 10% as required by oxygen delignification, extended cooking and similar processes (Harsent 1990, McCubbin 1990, and Verloop 1989). Many have been developed and applied in the past few years.

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[32] *The "heat release rate" is essentially the feed rate of the fuel fired to the boiler multiplied by its calorific value.*

3.10.3 Reducing boiler load

SUMMARY It is often more practical to reduce the load on the recovery boiler than to increase the capacity of an existing installation. It is necessary to analyses the mass and energy balance of both the boiler and the complete kraft chemical system shown in Figure 11 on page 73. Careful consideration of the capacity of each piece of equipment in the system is required to determine which of the available techniques are technically and economically feasible. The items discussed below show that there are a number of ways of obtaining several percent additional capacity from many boilers. The list is not exhaustive since there is extensive scope for engineering ingenuity in this field.

Most mills already practice some of these techniques, but none practice all of them, so the attainable reduction in boiler load will vary from mill to mill. The simplest way of reducing load on the recovery boiler is, of course, to reduce the production of pulp. The economic cost of decreasing production will generally, however, be large and will be the least attractive option available to the mill.

If the **soap is separated** and sold, burned outside the recovery boiler or converted to tall oil, the heating value of the black liquor is dropped by 4% to 8%. Hardwoods would be at the low end of the scale, and softwoods, the top. Several Ontario mills already practice soap separation so the scope for using this technique for further reduction in boiler load is limited. The authors have assumed that this approach to reducing recovery boiler load is not available to any of the Ontario mills for the purposes of cost analyses in this report.

Oxidizing the black liquor, using well demonstrated processes, will reduce the heating value of the liquor by 2%.

Where a mill has inadequate storage for black liquor and other recovery cycle streams, the boiler never operates optimally, and can lose several percent of its capacity. At least one mill known to the authors has added 5% to its effective recovery boiler capacity by **increasing black liquor storage capacity** from 3 hours retention to 24 hours retention, which allowed the operators to adjust the boiler for optimum operation. This major improvement in capacity was, of course, possible only because previous operation was poor. The effect of increased black liquor storage on effective boiler capacity is very mill specific.

A number of mills in North America and Europe **transport black liquor to other mills for incineration**, sometimes buying back the white liquor produced. This is a practical solution for overloaded recovery boilers if there is a mill with spare capacity within about 300 km (McCubbin 1990).

As mentioned on page 62, addition of **anthraquinone** to the digester has been demonstrated to increase the pulping yield by up to 2.5%, which reduces the production of black liquor organic solids by up to 6%, corresponding to somewhat larger reduction in total solids load. Yield increases of 1% with **boiler load reductions of about 6%** are typical of mill operating practice.

At least one Ontario mill uses anthraquinone, and over 60% of Japanese mills and many others in the world do so. The operating cost of compensating for various increases in recovery boiler loads caused by the introduction of oxygen delignification is shown in Figure 9 on page 64. The capital cost is negligible. There is no evidence that this approach would be successful if the increase in boiler loadings is due to the introduction of extended cooking.

High-consistency liquor firing is gaining acceptance (Hyoty 1988). This involves installing an additional black liquor evaporator, sometimes known as a "super concentrator" to raise the consistency to around 80% dry solids. Such liquor is more difficult to handle than the conventional thick black liquor of approximately 70% consistency, but when burned, it generates less gas flow in the recovery boiler due to its lower water content. Since boiler gas flow is one of the key factors limiting capacity, it is probably possible to increase effective recovery boiler capacity by more than the 5% required to accommodate the additional solids in the black liquor.

Where steaming rate is the limiting factor on recovery boiler capacity, some improvement can be attained by **reducing the boiler feed water temperature and/or reducing the temperature of the combustion air** where it is heated by the steam coil air heater. Either of these techniques reduce the steaming rate by several percent.

Where **gas flow** is the limiting factor in boiler capacity, it is theoretically possible to compensate for at least 10% increase in boiler load by enriching the combustion air with oxygen. The boiler at the MoDo mill in Husum, Sweden has reportedly (Croon 1983) operated for a one week trial at 17% greater load with oxygen enrichment, but the cost was considered excessive. If oxygen enriched air is used for combustion, then the flame temperature increases, increasing radiant heat transfer to the lower water walls of the boiler, and will in many cases reduce the temperature at the entry to the boiler bank (McCubbin 1990). If ozone delignification becomes popular, the possibility of using the oxygen vented from the ozone reactor as combustion air to increase recovery boiler capacity will merit investigation.

3.10.4 Recovery boiler replacement

The foregoing measures demonstrate that there are many practical alternatives to replacing a recovery boiler when pulp production, installation of oxygen delignification or other change in mill operation results in a recovery boiler being overloaded. Some are primarily "stop-gap" techniques which allow a mill to maintain pulp production for a few months or years without having to incur the high capital cost of a new recovery boiler, while others are good investments in themselves.

However, a new, modern boiler offers a number of advantages, which serve to partially offset its cost. These include greater thermal efficiency, reduction of air pollution, reduced labour, and greater pulp production capacity. Recovery boilers generally have a useful operating life of about twenty years, so it is common for mills to install new boilers for non-environmental reasons from time to time.

3.10.5 Status of Ontario recovery boiler loading

Surveys have indicated that the recovery boiler is the bottleneck in mill production in approximately 30% of Canadian mills (Tran 1985, PAPRICAN 1985, McCubbin 1990). There are no such surveys available specific to Ontario. There were no engineering studies on the capacity of any of the operating recovery boilers provided to the authors, so assessments had to be made of the current status of each mill's capacity to burn liquor.

The status of recovery boiler loadings assumed by the authors for the purposes of cost estimates in this report is summarized in Table 13.

Table 13 Recovery boiler loading status assumed for cost estimates

Company	Town	Boiler status
Boise Cascade Canada Ltd.	Fort Frances	Probably recovery boiler limited
Canadian Pacific Forest Products Ltd.	Dryden	Probably recovery boiler limited
Canadian Pacific Forest Products Ltd.	Thunder Bay	Available capacity due to sulphite mill shut down in 1991 *
Domtar Inc., Fine Papers Div.	Cornwall	Recovery boiler limited
Domtar Inc., Containerboard Division	Red Rock	Available capacity
E.B. Eddy Forest Products Ltd.	Espanola	Recovery boiler limited
James River-Marathon Ltd.	Marathon	Available capacity
Kimberly-Clark Canada Inc.	Terrace Bay	Available capacity
Malette Kraft Pulp and Paper Co.	Smooth Rock Falls	New boiler under construction 1991

This table is based on information available to the authors, and should be confirmed by detailed engineering studies at each mill. It is presented in this report to define the basis for cost estimates.

* Capacity at Thunder Bay inadequate for train K5.

3.11 Mechanical-sulphite Spectrum of Pulping

SUMMARY About 40% of the pulp produced in Ontario is from a family of processes that can best be considered as a continuous spectrum from low-yield sulphite through high-yield sulphite, chemical and thermomechanical pulp, to the traditional groundwood pulping process. Both chemical and mechanical pulp are included in this spectrum, and are discussed in this section. The term ***mechanical-sulphite*** *has been adopted for these pulps, because there is no generally accepted terminology.*

It is ***conventional*** *to consider those pulps in this spectrum with yields of over 80% to be* ***mechanical pulp****, while those of lower yield are categorized as* ***chemical pulp****. Some characteristics of the spectrum from groundwood through to low-yield sulphite pulp are shown in Table 14 on page 105.*

3.11.1 Groundwood pulping

Also known as **Stone Groundwood (SGW)**, this was the earliest form of mechanical pulping used commercially, and is by far the most extensively used mechanical pulping process in Ontario.

In this process, logs are forced into contact with a revolving grindstone in the presence of water to reduce the wood to a mascerated fibrous condition. The water applied cools, cleans, and lubricates the stone and conveys the pulp away from the stone. A few percent of the organics in the wood are solubilized, causing the water carrying the pulp to exert a BOD when discharged, and to be toxic. Refer to Table 14 on page 105 for typical values.

The groundwood process has been in commercial operation for about 150 years, and until relatively recently, plants were traditionally designed and built with no consideration for effluent quality. The groundwood mills in Ontario have all been upgraded environmentally over the past twenty years to some extent, but the physical installations and the operating traditions present serious obstacles to operation with low effluent discharges.

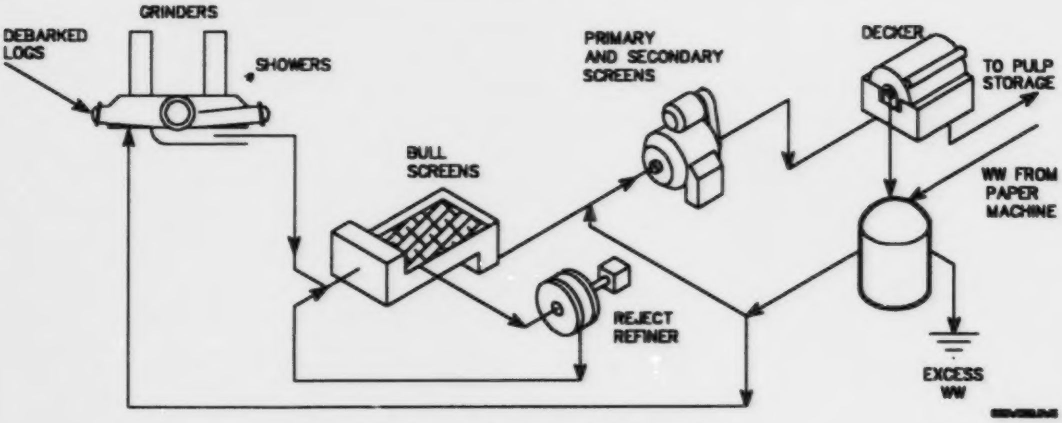

Figure 15 Groundwood pulping process

In principle, the effluent flow could be only a few cubic metres per tonne pulp, but the authors are not aware of any traditional, non-pressurized groundwood mill that has achieved this. The pulp from all groundwood mills in Ontario is used on site for paper manufacturing, normally newsprint, and the effluent flow from the mill depends to a large extent on the paper machine design and operation. Much of the BOD and toxic material that originates in the groundwood pulp mill will be discharged from the paper machine sewers.

A few modern groundwood mills have been built in the US and Scandinavia where the grinder operates under pressure, and the water system is designed to minimize flow, concentrating the effluent, as discussed in Appendix C. Mitchell (1990) reported on a Finnish newsprint machine integrated with a modern pressure groundwood mill where the total effluent flow was slightly under 9 m^3/tonne product.

3.11.2 Thermomechanical pulping

Thermomechanical pulp (**TMP**) is produced by chipping debarked logs, then separating the fibres in a device known as a **refiner**, where the chips pass between two serrated plates, one (or both) of which are rotating. This process requires almost twice as much power as the above mentioned groundwood process, but the mechanical properties of the pulp are substantially better. BOD and toxicity are increased, as indicated in Table 14 on page 105. TMP refiners operate under pressure, and at temperatures over 100 deg C. In one little used variation[33], the refiner operates at atmospheric pressure and a temperature of 100 deg C, producing a rather higher yield and presumably lower BOD.

3.11.3 Sulphite pulping

In sulphite pulping the fibres are separated by the action of sulphur dioxide and a metallic base, under pressure and at an elevated temperature. The traditional sulphite process is now generally known as **low-yield sulphite**, and is largely obsolete. However, the following hybrid pulping processes have been developed from the traditional process:

Chemimechanical Pulping	CMP
Chemi-thermomechanical Pulping	CTMP
High-yield Sulphite	HYS
Ultra High-yield Sulphite	UHYS

3.11.4 BOD generation by mechanical-sulphite mills

It is clear from consideration of the mass balance of a mechanical-sulphite mill that the quantity of organic material released from the wood is related to the pulping yield by a relationship of the form:

Organic loss % = 100 x (1-Yield) where yield is expressed as a fraction
loss is expressed as kg/tonne pulp

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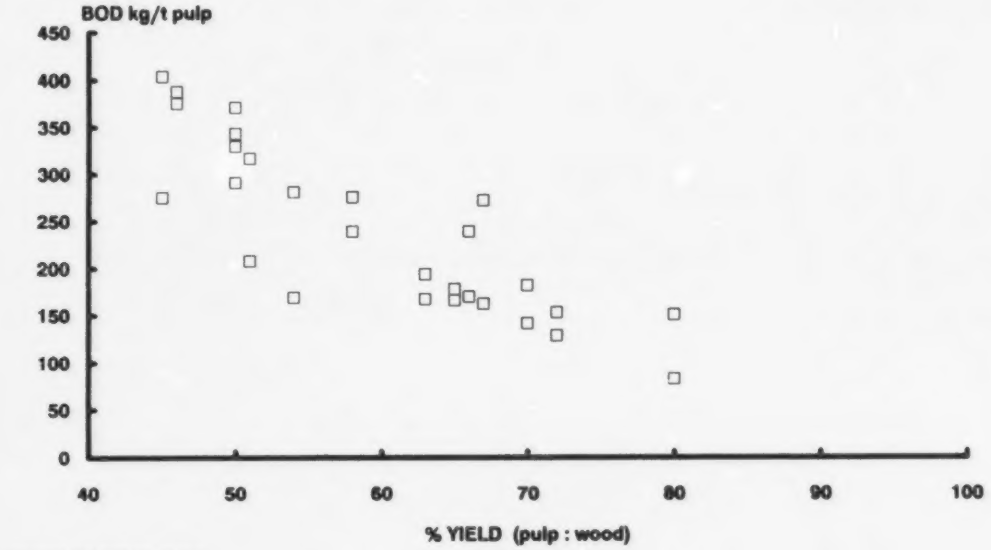
[33] *Refiner mechanical pulping (RMP).*

One can expect the BOD discharge to rise as the organic loss rises, but cannot expect any simple relationship, because there is a wide range of organic substances involved, some of which will degrade much more rapidly under the conditions of the BOD test than others. Figure 16 shows measured data from several sources for mills in the mechanical-sulphite spectrum. While there is a general trend of reducing BOD with increasing yield, the data show a great deal of scatter. In our own experience, this scatter is typical of such data for pulps in the mechanical-sulphite spectrum.



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All data are upstream of any effluent treatment, and without any chemical recovery process (Kocurek, Vol. 4, pg. 343)[34].

Figure 16 Yield: BOD relationship for various pulps in the mechanical-sulphite spectrum

3.11.5 Summary of pulping processes

Typical characteristics of the pulping processes of most interest to this report are summarized in Table 14. This tends to understate the complex and diverse industrial processes involved. The reader is cautioned that there will always be exceptional situations where data will fall outside the ranges given.

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[34] *Most figures in the report have the source computer filename shown in very small print. It is for editorial control and normally of no interest to the reader.*

Table 14 Typical characteristics of the processes and effluents of various pulping processes

Type of pulp	Yield	BOD kg/tonne	Effluent flow m^3/tonne	Principal pulping chemicals	Chemical feed (total inorganic) kg/tonne
Mechanical-sulphite spectrum of pulping processes					
Low-yield sulphite	45-55%	40-100[35]	100-300	Na, Mg[36], SO_2	450
High-yield sulphite	55-75%	140-250	50+	Na, SO_2	200-400
Ultra high-yield sulphite	80-90%	50-100	50+	Na, SO_2	150
CTMP	88-92%	40-60	8-25	Na, SO_2	50
TMP	90-95%	25-50	8-20	None	0
Pressurized groundwood	93-96%	11-20	8-20		
Traditional groundwood	93-96%	10-15	50	None	0
Miscellaneous pulping processes					
Kraft (unbleached)	43-58%	15-30[37]	50-100	Na_2S, NaOH	50 (makeup)
Kraft (bleached)	40-55%	20-50	50-200	Na_2S, NaOH	50 (makeup)
Semichemical	75-80%	80-120	15-100	Na_2CO_3, SO_2 (perhaps)	150
Deinking (non tissue)	70-90%	10-40	2-100	HOOH, NaOH, $NaSiO_2$	
Waste paper	95% +	5-10	10-100	None	None

Most of the pulping processes are used in mills where paper production is integrated with the pulping operation. The papermaking operation will generally not generate any BOD, but will generate a significant amount of wastewater. The discharges are mixed, so that while the above mentioned data on BOD generated indicate the total BOD in the effluent, the flows of wastewater will generally be much higher. The BOD discharge is characteristic of the process, whereas wastewater flows are quite dependent on equipment selected and operating practices, so can vary widely.

3.11.6 Discharge prevention at source

Apart from replacing the more polluting processes with more modern, less polluting ones, there are relatively few opportunities for significant improvements in effluent quality by in-plant process modifications for the non-kraft mills discussed in this report. The principal opportunity is the reduction of the effluent flow to lower the costs and/or improve the effectiveness of external treatment systems.

In the sulphite mechanical spectrum of pulps, the effluent BOD depends mostly on the pulping yield[38], which depends to a large extent on the product desired. It is common and not unreasonable to assume that the discharge of substances toxic to fish will rise as the pulping yield drops, but there are insufficient data available to quantify such an assumption, as discussed previously.

Effluent discharge prevention at source is discussed in further detail in Chapters 5 and 6.

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[35] *Assuming modern sulphite waste liquor recovery.*

[36] *Magnesium is the only low-yield sulphite pulping base used in Ontario.*

[37] *Assuming typical recovery of chemicals and waste liquors.*

[38] *An exception occurs when there is a chemical recovery system. In this case, the efficiency of chemical recovery has a major impact on BOD discharge.*

3.12 Semichemical Pulp

This type of pulp is often known as "NSSC", Neutral Sulphite Semichemical, but the technological advances mentioned below have made the inclusion of the term "neutral sulphite" in the name somewhat obsolete. Semichemical pulp is almost always used on site for the production of corrugating medium[39] in an integrated mill.

Delignification occurs by cooking wood chips in a pressure vessel, the digester, with (traditionally) sodium sulphite. The cooked pulp is discharged (blown) to a tank at atmospheric pressure, and pulping is completed using refiners. The sulphite cooking liquor is not reclaimed in either of the two mills in Ontario using the semichemical process, although many mills in the US and one in Canada (Cabano, Québec) do.

Several mills in North America have modified the process to eliminate sulphur from the cooking chemicals, and use sodium carbonate as the principal reagent. The foremost environmental benefit is that combustion of the spent pulping liquor produces sodium carbonate, that can be reused for cooking the pulp, but this is irrelevant if the mill does not recover the liquor. The Domtar mill at Trenton used the classic NSSC process in the past, but now uses a sulphur free modification, while the MacMillan Bloedel mill at Sturgeon Falls uses traditional NSSC pulping.

As indicated in Table 14 on page 105, the raw BOD for this type of mill, is high so biological treatment is relatively expensive. The effluent toxicity is relatively high, with the Sturgeon Falls mill reporting about 10% for the LC_{50} before installation of the anaerobic treatment system at that site.

3.13 Secondary Fibre Pulping

Secondary fibre pulping refers to the use of waste paper as raw material for paper manufacturing, and as a replacement or partial replacement for virgin wood pulp. There has always been some reuse of secondary fibre, and the rate of its use is rising rapidly.

Some waste paper has been used for many years as furnish for board and corrugating medium mills. This type of secondary fibre pulping operation is quite simple, with about 90%[40] of the purchased paper being converted to finished product. Waste paper is reduced to a pulp slurry by vigorous agitation in a tank full of water, generally known as a pulper. The use of non-deinked waste papers is generally restricted to production of various packaging grades, or as in one Ontario mill, the outer sheathing paper for gypsum wallboard.

Wastes produced consist of relatively heavy trash, which is collected in relatively dry form and fine fibres which are lost with the excess white water flows. The latter also contain a variety of soluble materials that are washed from the pulp, that will exert a BOD, and may be toxic to fish. As indicated in Table 14 on page 105, the BOD discharge is generally low.

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[39] *"Corrugating Medium" is the feedstock for the corrugators which produce the familiar corrugated intermediate layer in double wall "cardboard" boxes.*

[40] *The yields in such operations are substantially higher, and the generation of solid wastes substantially lower, than in deinking plants.*

The quantity of heavy trash, consisting of baling wire and staples, plastics, and miscellaneous garbage that finds its way into the waste paper handling systems before arrival at the mill, is variable, but is typically under 10% of the production rate, and would be much less in the case of higher grades of waste paper. This would normally be landfilled because it is difficult to handle and incinerate.

In most secondary fibre mills, it is technically feasible to recover all the solids that settle in a primary clarifier and use them as furnish to the paper machine. Some mills do so, including the Beaver Wood Fibre mill at Thorold. It is also technically feasible to close the water cycle completely, and operate with zero effluent (except for the heavy trash) for some, if not all secondary fibre (non-deinking) mills, but this is not the current practice in Ontario.

3.14 Deinking

Today, a modest but increasing proportion of the waste paper recovered in Canada is used in production of newsprint, tissue, and other paper grades of relatively high quality, which necessitate the removal of ink and virtually all other impurities. This cleaning process is generally known as **deinking.** After pulping of the waste paper and removal of gross contamination, surfactants are added to the slurry to separate ink from the fibres. The objective is to disperse the ink in very small particles that have minimal affinity for fibres, so the two can be separated, either by washing or by flotation.

Most older deinking plants in North America, including Noranda at Thorold, use a washing process to separate the ink particles. This is very different from the washing processes used in kraft and sulphite mills to recover soluble solids, because deinking washers are designed to avoid forming a mat of fibres, so that the small ink particles will not be retained. This results in loss of most of the fillers in the waste stock, as well as significant quantities of the fine fibres, and generates relatively large effluent flows, in the order of 50 to 100 m^3/tonne.

The flotation[41] deinking systems that are common in Europe, are now being installed widely in North America. In this process, fine air bubbles are injected into the stock, causing the ink particles to float to the surface where they are skimmed off. As in wash deinking, there is always some loss of fibre and fines. A flotation deinking process can be designed for effluent flows of under 10 m^3 per tonne pulp produced. This facilitates much more effective effluent treatment than in the wash deinking plants mentioned previously.

It is technically feasible to reduce the effluent flows from wash deinking systems by using flotation clarifiers, but this technology has not been widely adopted, perhaps because it was not developed until after flotation deinking had become the more popular process for new installations.

News grade deinking operations will discharge approximately 20 kg BOD/tonne product, whether the wash or flotation deinking process is used. The effluent BOD can be reduced to 30 mg/L or less by biological treatment, which corresponds to under 0.5 kg/tonne for a modern flotation deinking mill, or about 3 kg/tonne for an older design of deinking based on washing. This latter value corresponds quite closely with the USEPA's requirements for deinking mills that were set in the early 1980s, when wash deinking was the norm in the US.

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[41] *Many deinking plants in North America which are considered as using the "flotation" process include one stage of washing in the process, but still discharge much lower volumes of effluent than wash process mills.*

Deinking operations generate significant quantities of solid waste because the product yield is typically in the range of 70% to 85%, and the shrinkage appears mostly as a wet sludge[42]. One could say that the current US regulations requiring that significant proportions of some types of paper sold in the US contain recycled fibre will effectively result in the export of US solid waste to Canada, because Canadian mills will have to import and deink waste paper to survive in the US market. The latter is essential to most Ontario mills.

The sludge produced may be landfilled, used as an agricultural soil conditioner or incinerated. Both of the current Ontario deinking operations use their combined sludges as soil conditioners, mixing the deinking wastes with primary and waste activated sludges. The success of these operations is dependent on local soil conditions. Both landfilling and incineration create environmental difficulties.

Notice that as shown in Table 15, **a deinking operation may well generate over a tonne of waste sludge per tonne product,** if the yield is on the low end of the normal scale or the sludge dewatering is not very effective.

Table 15 Quantities of waste sludge produced by a deinking operation

Deinking yield*	Loss, tonnes/tonne product	Quantity of wet waste sludge produced after dewatering, tonnes/tonne of deinked fibre produced			
	100% dry	25% dry	30% dry	35% dry	40% dry
90 %	0.11	0.44	0.37	0.32	0.28
85 %	0.18	0.71	0.59	0.50	0.44
80 %	0.25	1.00	0.83	0.71	0.63
75 %	0.33	1.33	1.11	0.95	0.83
70 %	0.43	1.71	1.43	1.22	1.07
60 %	0.67	2.67	2.22	1.90	1.67
50 %	1.00	4.0	3.33	2.86	2.50

*The various values of yield and final sludge consistencies shown above include the full range of commercial operations. Yield is defined as the proportion of waste paper that is converted into usable deinked pulp. In most deinking mills, a quantity of biological sludge from the waste treatment plant and fibrous sludge from the paper mill would be added to the above quantities.

3.15 Brightening of Mechanical Pulp

Pulps manufactured by the foregoing processes range in colour from the dark brown of NSSC (and kraft) through various shades to a light straw. These colours are satisfactory for packaging and some other uses, including newsprint in some cases. The brightness of mechanical pulps is usually between 55 and 65, and can be raised to about 85 by bleaching for certain specialized uses such as personal hygiene products. If the pulp is to be used for making printing grades of paper, or products for personal use, it has been customary to bleach or brighten[43] it.

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[42] *This is in contrast to the mechanical and chemical pulping processes where shrinkage usually generates dissolved rejects. Most of the substances lost from the raw wood emerge dissolved in the effluent.*

Brightening can generate significant amounts of effluent of diverse characteristics, depending on the process selected, the desired brightness, the previous pulping process and species of wood used. Several of the mechanical pulp mills in Ontario brighten the pulp, but none practice the aggressive bleaching of the market CTMP mills in other parts of Canada.

The shrinkage during bleaching or brightening of mechanical pulp is likely to be less than 1%, depending on the conditions and chemicals used. The lost material is chiefly organic matter, adding to the mill's BOD discharge. In extreme situations, where a major improvement in brightness is desired, yield losses could be up to 4%, which could add up to 50 kg BOD/tonne pulp to the effluent. At least one bleached CTMP mill, outside Ontario, discharges over 100 kg BOD per tonne pulp.

Table 16 Brightening and bleaching processes for mechanical pulps

Process	Usual method of application	Brightness increase
Reductive processes		
Sodium bisulphite	Applied to grinders or to chips before refining	1-4
	in suitable vessels	up to 10
Sodium hydrosulphite	Added to pulp before entering brightening vessel or storage chest	3-6
Zinc hydrosulphite	Not environmentally acceptable	
Oxidative processes		
Calcium hypochlorite	Limited to hardwoods	
Sodium hypochlorite	Added ahead of storage chest	10-12
Hydrogen peroxide	Usually added to bleaching vessels, may be multi stage. Sometimes on wet machine	10-14
Oxidative / reductive processes		
Hydrogen peroxide and sodium hydrosulphite in series	Bleaching vessels	12-18
ditto two stage	ditto	25

The attainable brightness increases are indicative of performance where the process is suitably applied. "Bleaching vessels" refer to tanks, chests or towers that are dedicated to the brightening reaction, as opposed to storage vessels that are often used for the bleaching reaction, particularly when only a few points brightness gain are required.

In the Ontario mills within the scope of this report, which practice brightening, the objective is a gain of only a few brightness points. The shrinkage and hence BOD discharges are therefore low. The authors were unable to find any data that differentiate BOD or toxicity of effluent from mills brightening pulp to the extent currently practiced in Ontario.

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[43] *The terms "bleaching" and "brightening" are loosely interchangeable. Brightening generally implies a modest increase in brightness (a few points), while bleaching may be more ambitious.*

3.16 Paper Mills

SUMMARY A non-integrated paper mill consists of one or more stock preparation areas and paper machines. Stock preparation systems discharges small quantities of dirt and larger quantities of fibres (kg/tonne). The fibres can be recycled. The paper machine is normally of the Fourdrinier type with a moving wire. More modern ones may have twin wire, but this has little influence on the effluent quality. White water management is the most significant control technique for minimizing the effluent discharge, and is particularly important for twin-wire machines. Savealls are important control devices for coated paper machine operations.

A non-integrated paper mill consists of one or more stock preparation areas and paper machines. Normal auxiliary facilities may include some that effect effluent quality, such as a boiler plant, water supply and waste treatment plant. Others have negligible environmental impact such as paper finishing[44], wrapping, and warehousing.

At the present time there are eight mills in Ontario that operate as non-integrated paper mills, in that there is no pulp manufactured on site[45]. Five of those discharge effluents that are consistently non-toxic to trout, and one discharges a marginally toxic effluent.

The following general discussion on paper machines applies to integrated as well as to non-integrated mills. However, there is one important difference between an integrated and a non-integrated mill. In an integrated mill the pulp stock arrives at the paper machine at relatively low consistency so that the paper machines will always have an excess of process water. It is possible to return the excess process water, known as white water, to the pulp mill. There are a number of problems that may occur when white water is recycled. The mill effluent flow and rate of discharge of many contaminants is dependent on how successful the mill is in resolving these problems. For a more detailed discussion of this subject refer to White Water Management on page 187, and Effluent Flow Reduction on page 189.

3.16.1 Stock preparation

The various kinds of pulp and any additives required are blended and then passed through screens and centrifugal cleaners to remove physical contaminants. The main stock stream or a side stream may pass through refiners to modify the fibre properties before feeding it to the paper machine.

The BOD discharge is generally negligible, but can be several kg/tonne paper if there are significant starch, coating leaks, other losses due to equipment weakness or operator error. Good housekeeping is the prime control measure. The stock preparation area will not normally contribute to acute lethality of the effluent, and the authors found no evidence of such in Ontario mills.

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[44] *In this context, finishing refers to dry mechanical operations such as cutting to size. There would be no effluent, and the waste paper cut off the raw paper rolls is universally reused in the papermaking process.*

[45] *Five of the eight repulp waste paper.*

The only other environmental effect of the stock preparation system is the discharge of very small quantities (<1 kg/tonne) of dirt and several kg/tonne of fibre. This material will be removed from the effluent by the primary clarifier, and may contribute to the mill's total solid waste flow.

Due to the extensive recycle of water in paper mills, particularly those integrated with pulp mills, the above mentioned BOD and suspended solids may exit the mill at a point quite far removed from the stock preparation department.

3.16.2 Paper machines

The term "paper machine" is used for equipment that converts the low consistency stock from the stock preparation system into a roll of dry paper, ready for shipment or cutting into sheets. A typical flowsheet for a stock preparation system and the traditional type of Ontario paper machine is shown in Figure 17. The paper machine includes the headbox and all the equipment to the right of it.

A major difference between Ontario and other major newsprint producing regions is the stock furnish. Most major newsprint producers elsewhere, include groundwood, or TMP, and kraft pulp in the stock furnish. The latest technology is the manufacture of newsprint with CTMP as the only fibre furnish.

In the traditional Fourdrinier type paper machine, the stock from the headbox is first dewatered by being deposited on to a horizontal wire mesh conveyor belt, called the former. The stock is fed to the former at a consistency of about 0.3% to 1%, and leaves at about 20% consistency. It is then pressed between rotating rolls to raise the solids content to about 40%, and finally dried by passing it over steam-heated rolls. Any dissolved material, including oxygen demanding or toxic substances, contained in the water passing into the dryer will either be destroyed by the heat of the dryer, or become a constituent of the paper.

In an increasing number of modern paper machines, the forming section uses two wire conveyor belts, and the sheet of paper is formed between them. There is a wide variety of these double, or twin wire formers. While the differences between them have a major impact on paper properties and the grades of paper that can be manufactured on any one machine, they do not make much difference in discharges of waste to the environment. However, conversion of an older single-wire paper machine to twin wire can effect suspended solids discharges indirectly, because the consistency and volume of white water normally rises. This can result in increased discharges to sewer if the white water system is not upgraded simultaneously. The mills discussed in this report all have primary treatment systems that would capture most of the additional suspended matter discharged.

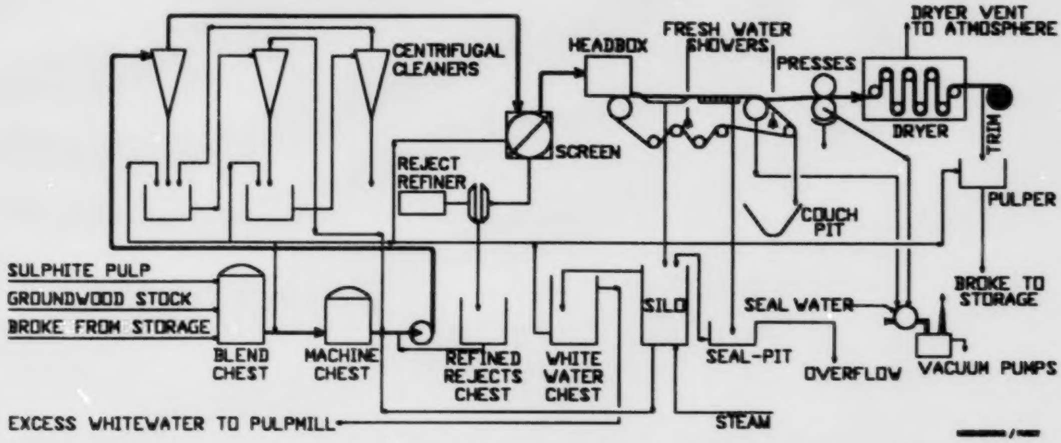
CENTRIFUGAL CLEANERS
HEADBOX
FRESH WATER SHOWERS
PRESSES
DRYER VENT TO ATMOSPHERE
DRYER
TRIM
SCREEN
REJECT REFINER
PULPER
COUCH PIT
SULPHITE PULP
GROUNDWOOD STOCK
BROKE FROM STORAGE
BLEND CHEST
MACHINE CHEST
REFINED REJECTS CHEST
WHITE WATER CHEST
SILO
SEAL WATER
SEAL-PIT
OVERFLOW
BROKE TO STORAGE
VACUUM PUMPS
EXCESS WHITEWATER TO PULPMILL
STEAM

Figure 17 Flowsheet of traditional newsprint paper machine with stock preparation system

3.16.3 Water balance

The paper forming process requires removal of 100 to 200 tonnes of water per tonne of pulp. The water contains significant quantities of fibres, and is known as white water. Most of it is recycled to the stock preparation system, while some must be discharged to sewer or recycled to other parts of the mill (shown as "excess white water" in Figure 17). Management of the white water system is the most environmentally significant item in controlling effluents from paper machines. When coated paper is manufactured; starch, latex, and other coating materials can be present, in addition to fibres, and may have an appreciable BOD.

Except for paper machines incorporating a coater, very little BOD or toxicity is generated in the paper machine area, so that the content of such substances in the effluent is dependent on the quantity carried into the machine with the pulp. As these pollutants are mostly soluble, the split between effluent and the paper sheet will be approximately in proportion to the ratio of flows of water into the dryer (normally about 1.5 tonnes/tonne paper) and the total effluent flow, (varying from a few tonnes/tonne paper to over 100).

4 EFFLUENT CHARACTERISTICS in 1990

SUMMARY Traditional wastewater parameters are reviewed along with some additional parameters, which are receiving increasing attention from scientists, industry, and regulatory agencies. The formation of non-chlorinated and chlorinated organics, including AOX and TCDD/TCDF, and the impact of trace metals are discussed. The data from the first six months of the 1990 MISA monitoring program are reviewed, and comments on the results for each mill are summarized.

4.1 General Wastewater Variables

SUMMARY Traditionally BOD, TSS and acute lethality were the principal parameters used for evaluation of wastewater quality. These provide a basis for examining only the short term and local effects of effluent discharges. In recent years attention in several parts of the world, including to some extent Ontario, has shifted to the longer term effects, requiring consideration of the content of persistent and/or bioaccumulative substances in the effluents. The 1990 MISA monitoring program included the determination of many of such substances known to be present in industrial effluents. COD and AOX provide indications of the total quantities of non and poorly biodegradable substances in the effluent. Analysis of individual substances would be more specific, but expensive and it is difficult to ensure that all substances are considered. In pulp and paper mill wastes, it is possible to draw useful inferences on the content of some compounds in the effluents from the known concentrations of related chemical species.

Effluent testing methods are well standardized in most developed countries, but national standards are often not equivalent to each other. In particular, Scandinavian practices are liable to lead to higher BOD and lower TSS and organochlorine values being reported relative to Ontario practices.

The ratio of chemical oxygen demand (COD) to BOD provides an indication of the biodegradability of the effluents. High values for this ratio, as found in well treated effluents indicate that little further reduction in organic content can be achieved by biological treatment.

Colour is a parameter of concern in some parts of the world but it is not included in the MISA program. Conductivity is a good indicator of the efficiency of process water usage, with low conductivity indicating that there is a good potential for success if a water conservation program is implemented

Traditionally, the following parameters have been considered for the evaluation of wastewater treatment plant performances: BOD, COD, DOC, TSS/VSS, NH_3/NH_4^+, NO_3/NO_2, Tot-N, Tot-P, and sulphide.

In recent years many scientists and several regulatory agencies, including the Ministry of the Environment in Ontario, have expressed increasing concern about other parameters. The substances currently of concern to the Ministry in Ontario are listed in Table 1 on page 22.

4.1.1 Biochemical oxygen demand

The oxygen demand exerted by the microorganisms during biological treatment is measured by the biochemical oxygen demand (BOD) test. The standard BOD test (APHA 1989) uses a five day sample incubation period at 20 deg C and this procedure is usually understood unless otherwise stated. (In Sweden and Finland seven days are commonly used. There is no precise conversion factor between the two values, but as a rule of thumb BOD_5 constitutes about 85% of the BOD_7 value). The five day test does not give an absolute measure of the ultimate oxygen demand of the liquid waste, but its long acceptance and the lack of a more reliable standard dictate its continued use. **All references to BOD in this report should be interpreted as BOD_5, unless otherwise noted.**

This test can also give an indication of how the effluent will affect the oxygen balance of a receiving water. Because the method involves the use of biological inoculum, the variation coefficient of the method is quite large and systematic errors are easily introduced, i.e. intercalibration exercises between laboratories proved the method less reproducible than many chemical analyses. However, BOD remains an important parameter for the design of treatment plants, and control of BOD in the effluent can be of importance for discharges to receiving waters that are vulnerable to oxygen depletion.

BOD represents the fraction of the organic substances in an effluent that the natural ecosystems can generally assimilate quite well, except that where the assimilative capacity of the receiving water is exceeded, local damage, sometimes severe, can occur. BOD by its nature measures only non-persistent, non-toxic pollutants, and many environmental scientists consider it unfortunate that its long, and often useful, history has led to such heavy emphasis on reducing discharges.

BOD and TSS were two of the most significant effluent parameters in pulp and paper mill wastes in the past, but are less important to-day because of the lower discharge rates and the development of more sophisticated knowledge of environmental effects. **They remain the most important design parameters for biological treatment plants, and are important in many kinds of wastewater, which has led to extensive data on performance being available, and sophisticated technology being developed for BOD and TSS control.**

4.1.2 Chemical oxygen demand

COD_{Cr} (or COD) measures oxygen demand of a sample by direct chemical oxidation (Chromic acid[46]) (APHA 1989). It is important to know whether or not the sample has been filtered prior to analysis. It is common practice in some European countries for the filtrate from TSS analysis to be analysed for COD. In this case the

$$COD \sim COD_{GF/A} + \tfrac{1}{2} TSS_{GF/A} \quad \text{or} \quad COD \sim COD_{70\mu m} + \tfrac{1}{2} TSS_{70\mu m}$$

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[46] *Another COD method exists using potassium permanganate. However, this is basically used in drinking water analysis and is of no relevance for pulp and paper mill effluents. Consequently, COD is used in this report as a synonym for COD_{Cr}.*

where GF/A refers to the glass fibre filters normal in North America, and 70 μm refers to the wire mesh common in Scandinavia. The results reported from Sweden in this report have been recalculated to unfiltered COD.

COD analysis can be performed quite rapidly, whereas it requires, by definition, 5 days to determine BOD. In many cases, COD may correlate quite well with BOD for a particular effluent. The difference between BOD and COD values for one sample provides an indication of the presence of persistent materials. The COD analysis is more precise method than the BOD analysis, thus it is considered by some to be better suited for legal enforcement than the BOD analysis. A suitable COD regulation can also protect the receiving water against oxygen depletion in the same way that the BOD regulation can be used. This philosophy is generally adopted by the Swedish Environmental Protection Agency. Efficient (90% +) biological treatment can remove in the order of 40% of the COD from pulp and paper industry effluents. Internal measures generally reduce COD in direct proportion to BOD. For example, modification of a digester system to use the recently introduced extended cooking technology could reduce both the BOD and the COD discharged by the subsequent bleaching operations by 45%.

The COD of a biologically treated effluent represents the fraction of the organic substances in an effluent that the natural ecosystems cannot readily degrade, but provides no indication as to whether these substances are harmful. Organochlorines are generally a fraction of COD, where the effluent sample originates in a process using chlorine.

COD/AOX or DOC/AOX ratios

The COD/AOX ratio reflects the chlorination rate of organic materials provided that the COD measurement is from the bleach plant, which is generally not the case for the MISA data. A low ratio, below 20, reflects a high degree of chlorination and conversely a ratio above 40 reflects a low degree of chlorination, comparable to that found in naturally occurring AOX.

4.1.3 Dissolved organic carbon (DOC)

DOC is an instrumental analysis in which a filtered water sample is burned and the evolved CO_2 is quantified by IR-detection, or it is catalytically reduced to methane which is subsequently burned and quantified in a flame ionization detector. Thus it is independent of the oxidation stage of organic carbon and does not include other elements such as hydrogen, sulphur, and nitrogen (APHA 1989). The method may readily be adapted to pulp mill effluents (Folke 1984, Folke 1985). DOC is not widely used at the moment, but the method could have a potential in wastewater characterization. For an individual effluent it is possible to correlate the measured DOC with COD and BOD. With bleach plant effluents, DOC has the advantage over COD in that the ratio between AOX and DOC is a direct measure of the degree of chlorination, i.e. the number of carbon atoms per chlorine atom. This is important in order to understand the nature of the measured AOX (see page 123). Unfortunately, the international data base on DOC is rather limited, causing some difficulty in interpreting the data collected.

4.1.4 Total Suspended Solids (TSS) / Volatile Suspended Solids (VSS)

TSS is determined by passing a known amount of sample through a filter paper and measuring the change in weight (APHA 1989).

The question of impact of TSS on receiving waters is confused by the fact that the TSS testing has historically been performed using a wide variety of filter media and methods, thereby making it difficult to evaluate comparable impacts from different dischargers on a uniform basis. Thus, the choice of filter is particularly important for pulp mill effluent due to the presence of fibrous materials. Filtration using glass fibre media is the generally accepted methodology in North America and apparently also within the EEC. However, a number of natural fibre filter papers have historically been used in non-standard methods. The glass fibre media filters always give higher TSS concentrations when compared to results obtained from the non-standard natural fibre filter paper. The exact magnitude of this difference varies widely with two to tenfold increases having been reported. Thus, any effluent TSS discharge limitation must be established with consideration to the analytical procedures.

In Sweden a 70 μm wire filter is frequently used for fibrous materials, and measurements can differ quite unpredictably from results obtained from paper or glass fibre filters:

$\frac{TSS_{GF/A}}{TSS_{70}}$ = from about 1.1 for concentrated samples to at least 5 for very dilute samples.

The differences between TSS values determined by the APHA (1989) method, using the fiberglass filters and the above mentioned 70 μm wire filter approach, are particularly marked when analyzing well treated effluents, since the suspended matter normally consists of small particles, is present at low concentration and is non-fibrous. The authors have generally avoided using Swedish data on treated effluent TSS when drawing conclusions on attainable values in this report, unless there was a clear statement that the analysis had been performed by a procedure very similar to that described in APHA (1989) and used in Ontario. For example, the data shown in Appendix C for TSS discharge from the Mönsterås mill do not reflect Ontario testing methods.

Suspended solids originate mainly from pulp fibre losses and biosolids formed in secondary treatment systems. In some locations it is important to minimize the discharge of TSS, since they may disrupt the receiving water ecosystem, depending on the characteristics. TSS discharged by a well operated biological treatment system will generally not settle in the receiving waters, and can often be considered as "fish-food". On the other hand, TSS has been found in some cases to carry bioaccumulative organic compounds, including polychlorinated dioxins and other toxicants that may adsorb onto the solids.

The characteristics of suspended solids discharged from to-day's mills are very different from those prior to 1970, which must be considered carefully when evaluating environmental effects.

Volatile suspended solids are a further characterization of the TSS in which the combustible organic content is determined. For pulp mill effluent the difference between TSS and VSS is generally low, but for paper mill effluents the discharge of fillers and coatings may result in greater differences.

Control of TSS and VSS depends strongly on the performance of the biological treatment system, if one is installed. Internal measures for fibre recovery, such as white water save-alls, effect discharges significantly where there is no biological treatment system.

4.1.5 Nitrogen and ammonia

The total amount of nitrogen compounds in an effluent can be determined by total Kjeldahl analysis. This method involves a decomposition of the organic substances by heating with concentrated sulphuric acid. Nitrogen compounds present in higher oxidation states than amines will have to be reduced by graphite or a similar agent prior to the digestion in which ammonium sulphate is formed. By adding sodium hydroxide, ammonia can be distilled off and the remaining liquor can be quantitatively back-titrated.

Not all organically bound nitrogen is accessible to plants and microbes to build proteins. A fraction of the nitrogen compounds, particularly from pulp mill effluents, is very persistent, but not necessarily toxic or bioaccumulative, and thus is of minor environmental importance. Another fraction of the total nitrogen can be removed in biological treatment plants.

Ammonia/ammonium ions are the most easily used nitrogen compounds. Ammonia is acutely toxic to fish (For rainbow trout LC_{50} = 1 mg/L free ammonia (Lloyd 1961)) whereas ammonium ions are not toxic. The Food and Agriculture Organization (FAO) water quality criteria for aqueous ecosystems is 0.025 mg/L at temperatures above 5 deg C and pH < 8 (Alabaster 1980). The concentration of free ammonia depends on temperature and pH:

$$pK_a = 10.0625 - 0.03325 * \text{deg C}$$

$$[NH_3]\% = \frac{100}{1 + 10^{pK_a - pH}}$$

Assuming a temperature in a river of 5 deg C and pH = 7.2, a concentration of free ammonia of 0.025 mg/L corresponds to a concentration of ammonia plus ammonium ions of 12.4 mg/L. At pH 8 this figure is reduced to 1.92 mg/L, but even at that pH the acute lethal concentration of ammonia plus ammonium is in the order of 80 mg/L. Therefore, in general ammonia toxicity is not a significant concern for pulp and paper mill effluent.[47]

In municipal sewage there is a surplus of ammonia/ammonium ions, so in order to reduce fish toxicity in that case there is an interest in oxidizing ammonia to nitrate in the course of biological treatment. This puts certain constraints on the design of municipal treatment plants, which are not relevant to pulp and paper industry effluent treatment, since these effluents are deficient in nitrogen compounds.

Nitrate and nitrite ions are probably a non-issue in pulp and paper mill effluents because of this deficiency of nitrogen compounds. Plants and bacteria prefer ammonia/ammonium ions to nitrate/nitrite ions as the source of nitrogen, because this saves them the energy for reducing nitrate.

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[47] *There have been reports of biologically treated pulp mill effluent being toxic to fish due to ammonia formation during storage/transportation from sample site to laboratory.*

The fraction of total nitrogen that is biologically available can vary widely from one mill to the other. Generally, the sum of the ammonium and nitrate nitrogen is the best indicator of the extent to which the effluent will contribute to eutrophication.

4.1.6 Phosphorus

Phosphorus may be incorporated into organic compounds, and may be present as polyphosphates, orthophosphates or similar compounds. The aqueous chemistry of phosphorus is very complicated and the interaction with heavy metals makes it very difficult to determine the environmentally desirable level, although it is desirable in most cases to reduce phosphorus discharges. For example, the presence of phosphates precipitates many heavy metals such as mercury and cadmium in the sediment. In Sweden there are examples where the presence of phosphate has made cadmium inaccessible to biota, and a lowering of the phosphate level in that particular lake increased the concentration of cadmium in fish from the lake. The same can be said about mercury and several other heavy metals (MFG 1991). Although excessive levels of phosphate are undesirable from a eutrophication point of view, it may not be desirable to lower the levels without consideration of the sink of heavy metals. For example, arsenic has severe effects on algae in lakes that are phosphorus limited, because plants mistake arsenic for phosphate in this case.

Phosphorus presents a dilemma to regulators of the Ontario pulp and paper industry. It seems to be generally agreed that most receiving waters in Ontario would benefit from reductions in phosphorus input, while the addition of the biological effluent treatment plants which can reduce BOD and other pollutants so efficiently will result in increased discharges of phosphorus.

Furthermore, lakes become less vulnerable to acid rain if levels of phosphates are not too low, because phosphate precipitates aluminium ions that are released at lower pH. Reasonable fish production is also dependent on the phosphorus level not being too low.

The Ascorbic Acid Method, 4500-P E (APHA 1989) is recommended for phosphate analysis, when being performed for operational control of biological effluent treatment plants, because it is superior in precision and accuracy to the Stannous Chloride Method 4500-P D (APHA 1989). The latter develops interferences when applied to some wastewater discharges (Jenkins 1991). Both procedures are described in APHA (1989).

4.1.7 Sulphur

Sulphide may be present in black liquor from kraft pulping. The presence of other sulphur compounds such as sulphate in effluents may lead to formation of sulphides under anaerobic or anoxic conditions. Sulphides are very toxic, especially under acidic condition due to the formation of H_2S. Still, sulphides are easily oxidized to sulphates under aerobic conditions in a treatment plant and are therefore a non-issue in biologically treated pulp and paper mill effluents.

4.1.8 Colour and turbidity

Colour and turbidity are not only of aesthetic concern, they can reduce the penetration of sunlight into low-flow receiving waters and impede the growth of water vegetation, thus creating an imbalance in the receiving water ecosystem. These variables are not covered by the MISA program, but in other parts of the world (e.g. India and Egypt) these variables are of the highest concerns, due to the aesthetic concern, and the use of polluted waters as drinking water.

4.1.9 Specific conductivity

Specific conductivity measures the ionized materials in the water sample, such as sodium, chloride, sulphate, ionized organics (acetic acid) and others. Pure water has very low conductivity whereas sea water has a high conductivity. Water with a high conductivity tends to be more corrosive than water with low conductivity, and corrosion is frequently cited as one of the principal limiting factors in reducing water usage and effluent flows in mills by internal recycle. Therefore, conductivity data provide a useful indication of the likelihood of a water conservation program being successful. (COD provides an indication of the extent to which high concentrations of organic substances may interfere with increased water recycle.) Bleached kraft mills in Ontario generally have conductivity exceeding 1500 μs/cm, but in some cases conductivity is closer to 1000 μs/cm, indicating possibilities for water savings. Ontario newsprint mills have conductivity exceeding 1000 μs/cm. Non-integrated paper mills will have lower conductivity than kraft mills, and frequently COD is the limiting factor for water closure of these paper mills. Still, waste paper mills with little or no effluent will have corrosion problems due to ions. Generally, where conductivity is low relative to similar mills, the prospects for implementing a successful water conservation programme are good.

4.1.10 Toxicity

In Canada, including Ontario, the term "toxicity" is used very widely, without qualification to refer to acute lethality to rainbow trout in a 96 hour test. Generally, the authors of this report have adopted this approach, despite its lack of acceptance elsewhere, and the potential for confusing the reader who is not familiar with the history of regulating industrial effluents in Canada over the past 20 years by a variety of "toxicity tests", all based on variations of the 96 hour LC_{50}.

In the context of this report, "toxic" and "toxicity" generally refer to acute lethality to rainbow trout (96-hour LC50) or *Daphnia magna* (48-hour LC50), as determined by the Ministry's standard tests.

The following terms have been adopted by many toxicologists associated with the "Group of Experts on the Scientific Aspects of Marine Pollution", which is an international body supported by the UN, and other international organizations, to describe various levels of toxicity:

LC_{50} < 1mg/L	Highly toxic
LC_{50} 1-10 mg/L	Moderately toxic
LC_{50} 10-100 mg/L	Slightly toxic
LC_{50} 100-1000 mg/L	Practically non-toxic
LC_{50} >1000 mg/L	Non hazardous

This terminology is intended to be used to describe pure chemicals, or commercial products. It is also applicable to specific compounds or groups of compounds (e.g. resin acids) in pulp mill waste, but is hardly relevant to the very dilute concentrations found in mill effluents.

There were no data on sub-lethal or chronic toxicity of the Ontario mill effluents collected during the 1990 MISA monitoring program. Sprague (1991) and Bonsor (1988) emphasized that such effects may be more significant than acute lethality, so the present authors have commented on the extent to which the alternative technology trains for kraft mills discussed in Chapter 7 may reduce such effects.

Two recent reports prepared for the Ministry of the Environment discussed the environmentally important aspects of pulp and paper mill effluent toxicity in considerable detail (Sprague, 1991 for non-kraft mills and Bonsor, 1988 for kraft mills). Since one of the authors of the present report was a co-author of both, it is necessary to mention the following points:

> **The previous reports questioned the ability of biological treatment plants to produce non-lethal effluents consistently. Evidence from recent installations, discussed in the present report, has demonstrated that it is now possible to design, build and operate effluent treatment systems which will consistently pass the current acute lethality test.**
>
> The previous reports made many recommendations on modifications to Ministry policy and procedures with respect to toxicity of pulp and paper mill effluents. These have NOT been considered by the present authors, who have accepted the established MOE policy, in accordance with the mandate.

4.2 Resin Acids

SUMMARY Resin acids are synthesized naturally in trees and may be more concentrated in effluents from mechanical pulping than from chemical pulping operations. In kraft mill effluents high concentrations may mean excessive losses of black liquor.

Resin acids are naturally occurring compounds in wood resins, particularly in pine and spruce. The amounts are particularly high in concentrated effluents from mechanical effluents. If equally high amounts of resin acids are found in kraft mill effluent, their origin is frequently spills of black liquor and soap or black liquor carry-over (perhaps poor brown stock washing). Figure 18 shows the resin acids found in softwood.

Resin acids are also found in lower concentrations in mills using recycled unbleached stock.

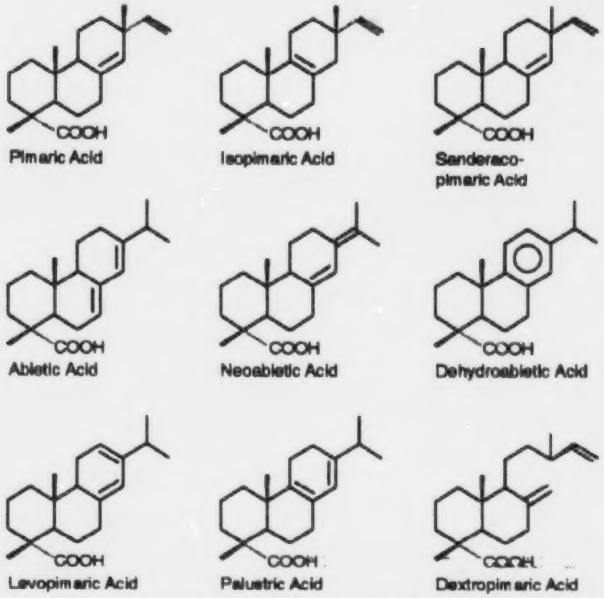

COOH
Pimaric Acid
COOH
Isopimaric Acid
COOH
Sanderaco-
pimaric Acid
COOH
Abietic Acid
COOH
Neoabietic Acid
COOH
Dehydroabietic Acid
COOH
Levopimaric Acid
COOH
Palustric Acid
COOH
Dextropimaric Acid

Figure 18 Resin acids found in softwood

A major fraction of the toxicity towards fish originates from fatty and resin acids (McLeay 1987). In the case of the Mönsterås kraft mill mentioned in Appendix C (SSVL 1990), about 14 g/ADt of resin acids (0.2 g/ADt is dichlorodehydroabietic acid), 8 g/ADt of saturated fatty acids and 1 g/ADt of unsaturated fatty acids were reported in the untreated effluent. Resin acids and unsaturated acids are reduced below 1 g/ADt by the biological treatment system, whereas saturated fatty acids are reduced to only 5 g/ADt.

The discharge rates of resin acids found during the 1990 MISA monitoring program were quite variable. Details are in Appendix B. Discharges from the kraft mills are summarized in Figure 19.

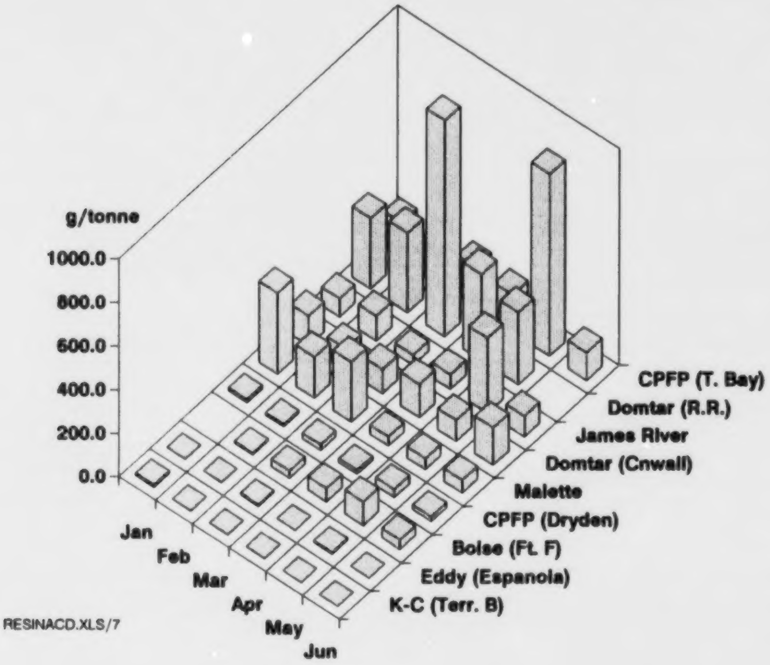


Figure 19 Resin acid discharges from kraft mills

The mills with biological treatment systems which discharge low quantities of BOD have very low resin acid discharge rates. Other mills are higher, with the two kraft mills which also manufacture mechanical pulp having the highest discharge rates.

4.3 Neutral, Non-chlorinated Compounds

Benzene and alkyl-substituted benzenes such as toluene, xylenes and styrene are all constituents of gasoline and many solvents such as mineral turpentine. They are aerobically degradable and the low-mass ones can be purged during aeration. In the atmosphere these compounds react with hydroxyl radicals and ozone, e.g. in the case of styrene with a half-life of about 2.5 hours (Howard 1989). Minor amounts of these compounds in effluents do not present any significant environmental problem.

Polyaromatic hydrocarbons (PAH) originate from crude oil or incineration processes. They are widespread in the environment and possibly also in pulp mill effluents, although their source is unlikely to be the pulp manufacturing process. These compounds are generally bioaccumulative and highly toxic so environmental exposure should be minimized. The only known technology for reducing their presence in pulp and paper mill effluents would be to avoid the use of petroleum products, or more realistically to avoid leaks of these oils to sewers. Addressing this issue specifically in pulp mill effluents may not be the most cost effective way of reducing environmental exposure.

4.4 Adsorbable Organic Halogen (AOX)

SUMMARY AOX is an analysis of organohalogens that are adsorbable on activated charcoal. In a pulp mill effluent AOX is an approximate measure of total organochlorine compounds. It consists of approximately 80% high-molecular mass materials (> 1000 dalton), 19% relatively hydrophilic (water soluble) low-molecular mass compounds, 0.09 % relatively lipophilic (fat soluble, potentially bioaccumulative) compounds, and 0.1% highly lipophilic (bioaccumulative) compounds. The exact composition varies considerably depending on its origin. Low chlorinated AOX is proven to be biosynthesized in aquatic and terrastic ecosystems.

AOX is an approximate measure of the total chlorinated organic material in the effluent. The materials include chemically unstable fractions that can be dechlorinated by chemical action or can be partially broken down in biological treatment plants. Some components remain persistent and may remain in the environment for sometime. AOX is an attempt to quantify the mass of chlorinated compounds formed but falls somewhat short. Nevertheless, it measures more of the total amount than any other currently used single analytical test.

AOX is an instrumental analysis of organically bound halogens (chlorine, bromine, iodine) that can be adsorbed on granular activated charcoal. In pulp and paper mill effluents, chlorine is the only halogen present in significant quantities. Organohalogens that are not adsorbable on this charcoal bed are not included in this analysis. The Swedish TOCl analysis is similar in that it uses XAD-resin to adsorb and desorb organochlorines to analyse different fractions. The actual chemical composition of effluent AOX varies from one effluent to another, and two AOX samples cannot easily be compared. For example, the ratio of chlorine to carbon varies significantly. One AOX figure may arise from high-chlorinated matter with a significant proportion of bioaccumulative compounds, whereas another figure may arise from low-chlorinated matter that is equivalent to the organochlorine matter that is biosynthesized in aquatic ecosystems (Grimwall 1991). In all cases a fraction of AOX consists of chemically unstable or readily biodegradable materials, which are easily mineralized (decomposed to harmless chloride) in any biological treatment plant. The AOX materials which are not mineralized during biological treatment may be regarded as more persistent in the environment, and a fraction of this material may even bioaccumulate. Therefore, this AOX fraction is potentially the most hazardous one.

Extractable organochlorines (EOCl) using hexane and persistent extractable organochlorines (EPOCl) (treatment with sulphuric acid adsorbed to kisel gel) were also determined in the Mönsterås study mentioned in Appendix C. EOCl was reduced from 8.5 g/ADt to 1.5 g/ADt during treatment, whereas EPOCl remained approximately the same at 0.5 g/ADt. Earl and Reeve (1989, 1990) reported laboratory values for EOCl being closely related to the amount of chlorine used in the first bleaching stage. The sequence D_{50}CE on a Kappa 30 unbleached pulp and a chlorine multiple of 0.14 resulted in EOCl of 12 g/ADt being formed (Earl 1989, 1990).

Conventional chlorine kraft bleaching leads to a high molecular mass fraction with the elementary composition (IPK 1982):

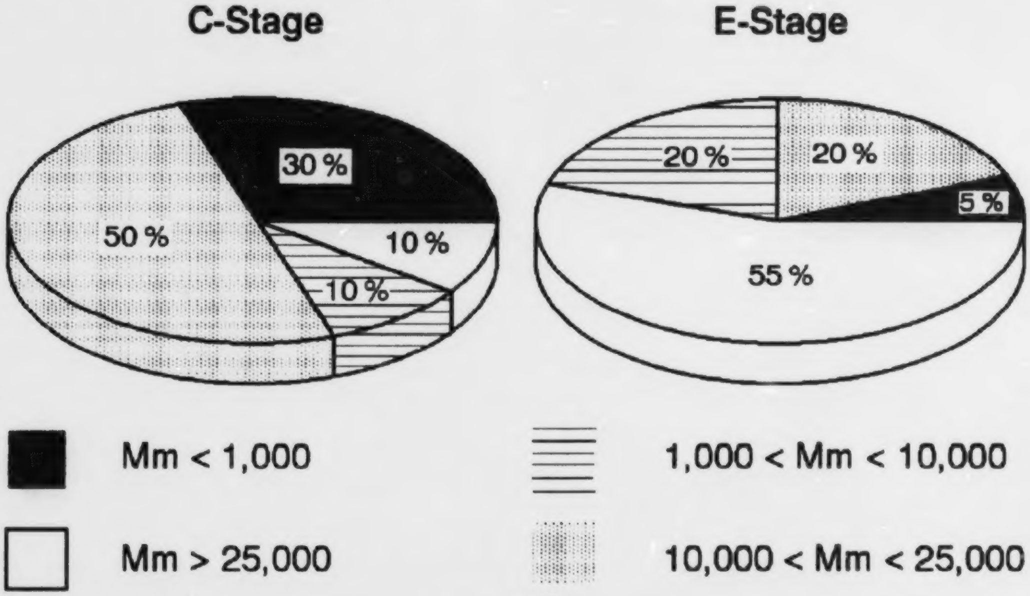
Untreated: $C_9H_9O_4Cl$ to $C_{10}H_{14}O_7Cl$

An atomic analysis of the high-mass fraction of AOX at Mönsterås gave the following elementary composition (SSVL 1990):

Untreated: $C_{27.7}H_{31.8}N_{0.1}O_{17.5}S_{0.4}Cl_{1.0}Na_{0.4}Ca_{1.2}$

Treated: $C_{29.7}H_{38.1}N_{0.3}O_{19.2}S_{0.8}Cl_{1.0}Na_{0.9}Ca_{1.4}$

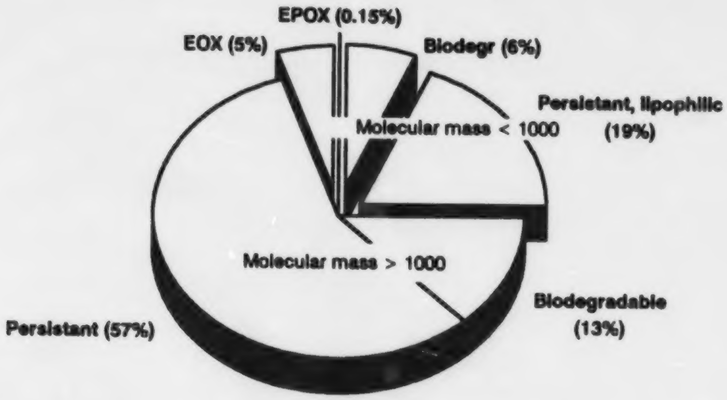
Apart from insignificant hydrolysis, biological treatment does not seem to affect the elementary composition of this high mass material. An oxidative degradation and subsequent analysis of aromatic carboxylic acids revealed the same kind of aromatics as are the precursors for the chlorophenolics. There were insignificant differences in the findings in the treated and untreated effluent. Molecular masses show maxima in the range from 1,500 to 15,000 for both treated and untreated effluents. The chlorination ratio of aromatic structures is somewhat lower for this high mass material than for low mass compounds. Conventional chlorine bleaching without O-stage predelignification causes discharges of effluent with the breakdown of components generally as shown in Figure 20.



Source: IPK 1982

Figure 20 Molecular mass distribution of the TOCl in conventional C- and E-stage effluents

A typical example of the breakdown of the types of organochlorines that are to be found in an untreated softwood kraft effluent is shown in Figure 21. The AOX of the effluent was 1.9 kg/ADt. The annual average reduction of AOX across the ASB at the mill was reported to be 42%, corresponding to 1.1 kg/ADt in the treated effluent. About 20% of the production is based on hardwood, so the combined annual figure is below 1 kg/ADt (Appendix C). A fraction of the EOX is also biodegradable.



JPIEFIGS.XLS Chart 2

Untreated bleached softwood kraft pulp mill effluent from Mönsterås. Data has been recalculated from SSVL (1990)

Figure 21 Approximate composition of AOX

Figure 21 presents an estimate of the constituents making up the AOX of untreated effluent at Mönsterås based on the discussion in Appendix C where the data originate from the "three bleach line" study in Sweden (SSVL 1990). The sample of treated effluent used in that study is slightly higher in AOX than the annual average AOX figure: 1.3 kg/ADt versus 1.1 kg/ADt for softwood. The study indicated a reduction of AOX from 2.1 kg/ADt to 1.3 kg/ADt, whereas the TOCl was correspondingly reduced from 1.6 kg/ADt to 1.2 kg/ADt, thus indicating a greater difference between AOX and TOCl in untreated effluent (2.1 kg/ADt and 1.6 kg/ADT) than in treated effluent (1.3 kg/ADt and 1.2 kg/ADT). Figure 21 is based on the TOCl analyses and is not consistent with the 42% reduction of AOX during treatment mentioned above.

The Extractable Organic Halogen (EOX) method has not been standardized. If analyzing for EOX, an appropriate protocol distinguishing EOX from POX (Purgeable organohalogens) should be used. Otherwise EOX may just be an unrevised estimate of chloroform.

4.4.1 Calculation of AOX content of effluents

SUMMARY An equation was developed to predict the AOX discharge rate for possible process modifications. It is similar to equations used by others, but coefficients were adjusted to fit known data on the Ontario kraft mills gathered during the 1990 MISA monitoring program.

To evaluate alternative processes for improving mill effluent quality, it is necessary to be able to predict the AOX discharge rate for any proposed process modification.

Germgård (1983) proposed the following equation for calculation of the organically bound chlorine (TOCl)[48] discharge from kraft bleach plants, and it has become quite widely accepted.

$$\text{Organically bound chlorine} = k \times (C + \frac{H}{2} + \frac{D}{5})\ \text{kg/tonne pulp}$$

where k is a constant in the range 0.07 to 0.11 if C,H, and D are in the units kg/tonne pulp and the Organically bound chlorine is determined according to the TOCl analysis procedure described by Sjöström (1981)

C is total molecular chlorine charge

H is hypochlorite charge, as equivalent molecular chlorine (=1.05 x NaOCl)

D is chlorine dioxide charge as equivalent molecular chlorine (= 2.63 x ClO_2)

The authors reviewed a number of publications, and discussed the problem of predicting AOX discharges with several scientists with extensive experience in measuring AOX discharges, and the consensus seems to be that the above mentioned equation is the best available at present, but that selecting the appropriate value for "k" is open to some discussion. It appears that the value of "k" should decrease somewhat for chlorine dioxide substitution over 70% (Liebergott 1991).

The above equation has been quite widely used in Scandinavian literature. Many statements in both Scandinavian and North American literature which one might presume to be based on chemical analysis of mill or laboratory effluent streams are actually based on the equation; although the authors rarely mention the value they selected for the "k" factor.

The data available from the 1990 MISA monitoring program (MISA 1991) provide more information on mill AOX discharges than has been available in the past, since analyses were conducted three times a week. Unfortunately the relevant mill operating conditions and effluent treatment plant input AOX concentrations were not recorded simultaneously, so it is not possible to conduct a rigorous comparison of the foregoing equation with the measured AOX discharges.

Earlier literature proposed values from 0.05 to 0.07 for k, but analysis of the MISA monitoring data (MISA 1991) indicates that a **value of 0.08 is the most appropriate for "k", up to 70% substitution, but that lower factors are appropriate for higher substitution levels**. The foregoing equation ignores any treatment of the bleach plant or whole mill effluents, but a review of the literature and comparison with the data in MISA 1991 indicates that an **aerated stabilization basin can remove approximately 40% of the AOX entering.**

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[48] *In this section, note that "TOCl" refers specifically to the values obtained by analysis using intrafiltration and XAD resin according to Sjostrom (1982).*

The original equation proposed by Germgård was based on bleaching with chlorine dioxide substitution rates under 70%. Liebergott (1991) presented curves indicating effectively that "k" declines at substitution rates over 70%. The authors have therefore used a modified value for "k" as follows where substitution is over 70%:

The calculations of AOX discharges in this report are based on:

$$AOX = k \times (C + \frac{H}{2} + \frac{D}{5}) * (1-e_B) \text{ kg/tonne pulp}$$

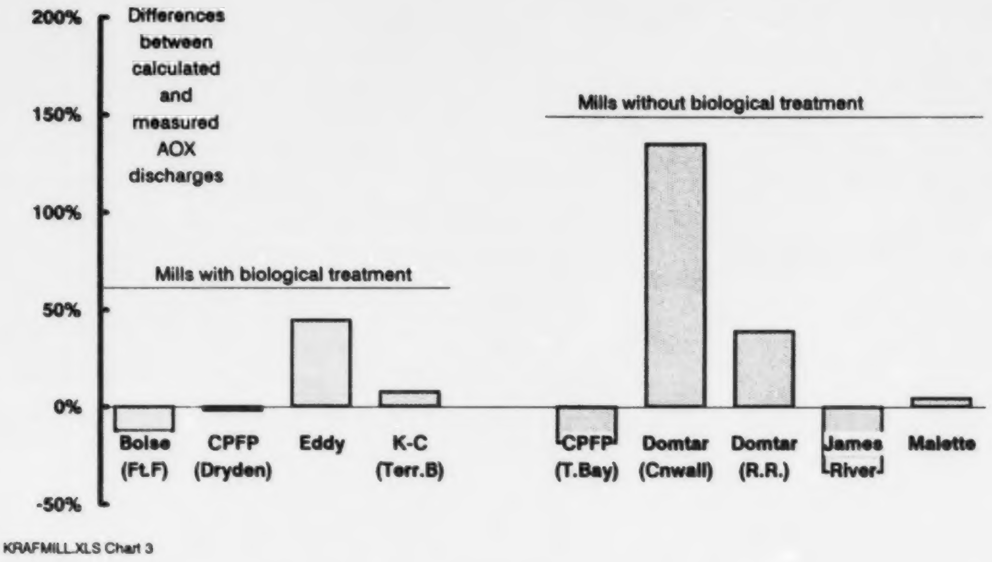
Where e_B is the AOX removal efficiency of the biological treatment system,
40% for ASB,
33% (Rempel 1991) for activated sludge.

$k = 0.08$ when the bleach plant is operating with less than 70% chlorine dioxide substitution in the first stage, and
$k = 0.08 \times (1.7 - (\frac{\%\ \text{substitution}}{100}))$ where substitution is greater than 70%.

Andrews (1991) and personal communication with several mill staff responsible for full scale pulp production trials with 100% chlorine dioxide substitution confirm that the values calculated from these equations are realistic.

The right-hand side of Figure 22 shows the errors which result when the foregoing approach is applied to the five mills in Ontario which did not have biological treatment systems in 1990. The Domtar (Cornwall) mill shows by far the greatest error. The authors speculated that the AOX discharged from the bleaching operation was being reduced by reaction with black liquor in the sewers. The mill makes a practice of ensuring that the brown stock screening operation, which is installed generally as shown in the traditional kraft mill flowsheet on page 73, washes the pulp as well as possible to minimize organics entering the chlorination stage. Since the black liquor solids removed by the washing action inherent in the screening operation are discharged to sewer, this results in the organics and sulphide being available to reduce AOX concentrations by reactions similar to those described by Milosevich (1991). Domtar advised the authors (personal communication from Paul Tessier, Co-ordinator Environment, Domtar, Montreal June 91) that their data have indicated that the AOX leaving the bleach plant was identical to that measured by the MISA program in the final effluent. The reasons for the unexpectedly low AOX discharge by the Cornwall mill must therefore remain unknown. If the wood species used at Cornwall are the reason, then the final effluent AOX achieved by any of the technology trains will be lower than predicted.

The Domtar (Red Rock) mill operated with a relatively high brown stock washer loss (approximately 30 kg/tonne as saltcake) at the time of the sampling, so a similar reaction could perhaps explain the low AOX discharge.

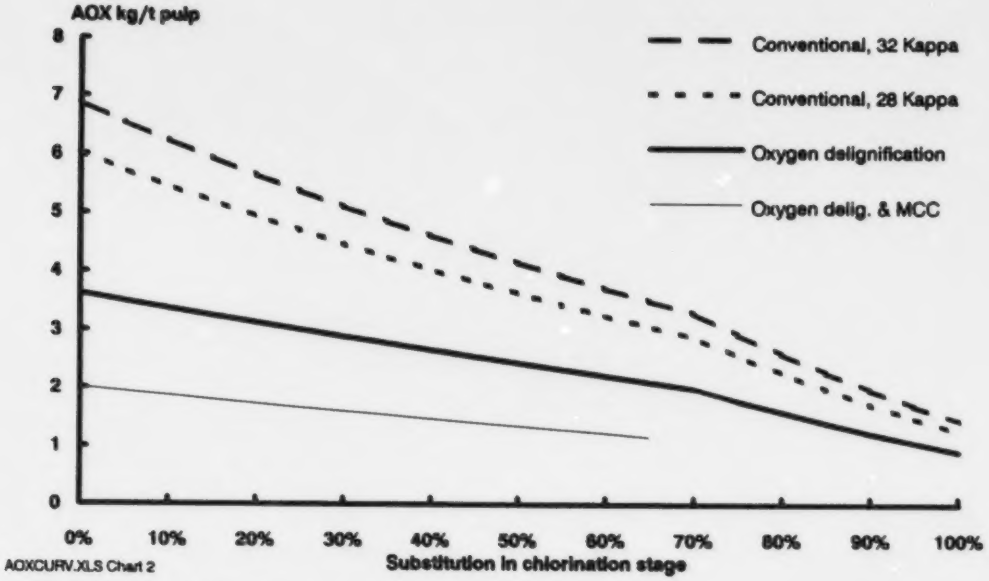


Positive values indicate calculated values > measured

Figure 22 Calculated vs measured AOX for Ontario kraft mills

The left-hand side of Figure 22 shows the errors between the above equation and the measured data for the four mills with biological treatment. The error is very small, except for the E.B. Eddy (Espanola) mill, where it is known (Cook 1990) that there is a gratuitous reduction of at least 10% AOX in the sewer system, which is believed to be caused by reaction with boiler ash.

The authors concluded that the above equation is satisfactory for the purposes of this report. However, while it is **probably as reliable as many of the calculations used in designing mill processes, it must be recognized that the prediction of AOX discharges is far from an exact science**, and lacks the years of experience underlying predictions of discharges of traditional pollutants. The curves in Figure 23 present the results of calculations from this equation for various pulping and bleaching conditions, for softwood pulps. Bleach chemical demands were calculated from the data presented in Figure 12 on page 78.



AOX discharges prior to biological treatment. Calculated by the authors using the equations discussed in text.

Figure 23 AOX discharges for various pulping and bleaching conditions (softwood)

AOX discharges from hardwood will normally be substantially lower, since lesser quantities of chlorine based compounds are required to bleach hardwood.

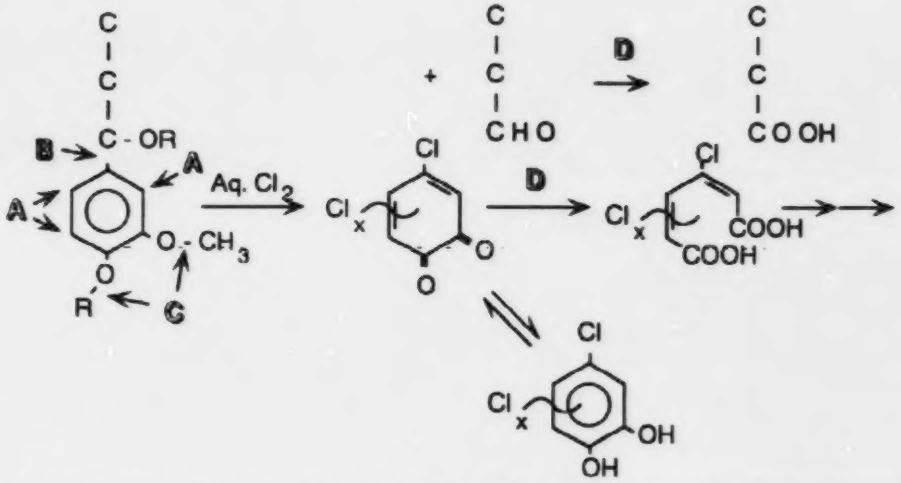
4.5 Formation of Organochlorine Compounds

SUMMARY The reaction of chlorine and/or hypochlorite with lignin residuals from the cooking process creates organochlorine compounds. These take many forms and those that have been identified total in excess of 300 compounds. Of these compounds the chlorophenolics are probably the better known group of compounds.

The main pathway for the formation of organochlorine compounds is by reaction of elemental chlorine or hypochlorite with lignin residues from the cooking process.

4.5.1 Chlorophenolics

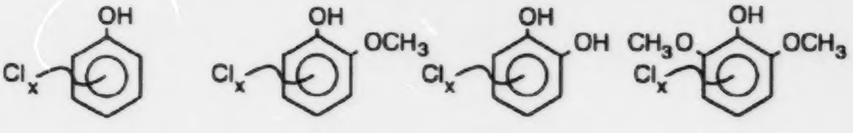
Chlorophenolics are formed in the C-stage after electrophilic sidechain displacement reactions of lignin residuals which can be followed by one or several aromatic substitution reactions (up to four chlorine atoms may be added to non-chlorinated phenolic precursors). Precursors may originate from the delignification processes occurring during cooking or by the oxidation reactions of chlorine. Often chlorophenolics formed in the C-stage are only extracted in the E-stage due to the nonionized (water insoluble) form they have in the C-stage.



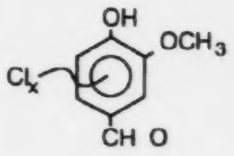
A = Electrophilic aromatic substitution; B = Electrophilic sidechain displacement; C = Aliphatic ether cleavage; D = Further oxidation reactions.

Figure 24 Reaction pathways for lignin residuals with chlorine

The phenolic structures that may be formed by these reactions are summarized in Figure 25.



Phenol Guaiacol Catechol Syringol



Vanillin

Spent bleach liquors from hardwood and softwood fibres

Figure 25 Chlorophenolics reported (IPK 1982)

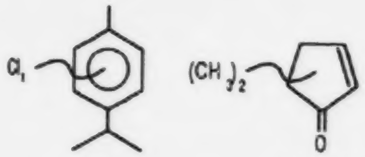
The type and amount of chlorophenolics to be found in different spent bleach liquors depend on the raw material, the pulping process and the amount of chlorine used for bleaching. Spent bleach liquors from softwood kraft pulp normally contains the highest amounts of chlorophenolics, i.e. the chlorinated phenols, guaiacols, catechols, and vanillins. Spent bleach liquors from hardwood pulp contain smaller amounts than softwood, but syringols may be present, which are not found in softwood effluents, as precursors are lacking in the softwood lignin.

Recent results from the Mönsterås mill studies indicate that when oxygen delignification is used prior to a C/D stage with a low chlorine multiple, mainly dichlorinated phenolics are formed (~27 g/ADt) with less monochlorinated (~7 g/ADt) and trichlorinated phenolics (~10 g/ADt). Hardly any tetrachlorinated phenolics are formed during bleaching (SSVL 1990). The same study includes data on the ASB performance which also indicate that monochlorinated phenolics are essentially removed, and dichlorinated phenolics are reduced to one-third, whereas tri- and tetrachlorinated phenolics resist biological degradation in the treatment system. (The latter types of phenolics are by far the most hazardous fraction). The total reduction of chlorophenolics during ASB treatment was 58%. These types of chlorophenolics are derived from phenols, guaiacols, catechols and vanillins as could be expected from softwood pulping. The total level of chlorinated phenolics (40 to 45 g/ADt) is significantly lower than reported from bleach plants without O-stages (80 to 250 g/ADt).

The presence of di- and trichlorophenols found during the MISA program in a bleach plant effluent can be taken as an indication of the presence of chlorinated guaiacols, catechols and other lignin related chlorophenolics as well[49]. The other chlorophenols analysed in the MISA program, i.e. 2,3,4, 2,3,5, 2,4,5-trichlorophenols, tetrachlorophenols and pentachlorophenols cannot be formed from direct chlorination of phenol at atmospheric pressure, and probably originate outside the bleach plant itself, e.g. wood preservatives.

4.6 Lipophilic, Neutral Organochlorines

Around 60 lipophilic pollutants have been identified by GC/MS (gas chromatograph/mass spectrometry) analysis in the effluents from Mönsterås. Most of those were reduced significantly during biological treatment in ASB, but higher chlorinated ones tend to be more stable. Treatment with sulphuric acid eliminated most of the lipophilic compounds except chlorinated phenolics, chlorinated and non-chlorinated p-Cymens and trimethyl-2-cyclopentenone.



p-Cymen

Trimethyl-2-cyclopentenone

Figure 26 Compounds that are not degraded in biological treatment (ASB)

Chloroform, chloro-acetones, aldehydes and acetic acids may be formed in both C, E, and H pulp bleaching stages (Dallons 1990, Hrutfiord 1990):

The H-stage is by far the largest chloroform producer, 150 to 200 g/ADt or 5 to 15 times the magnitude of C, E, and D-stages combined, and the magnitude of the hypochlorite charge is the dominant factor affecting the amount of chloroform produced in the H-stage. The classical haloform reaction is the main reaction responsible for chloroform formation from methyl-ketones (from lignin precursors). This reaction is most efficiently catalyzed by alkaline conditions as shown in Figure 27.

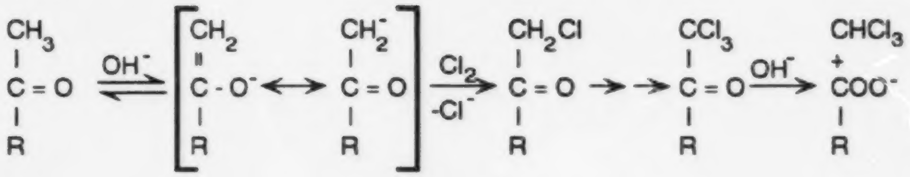
---

[49] *The 1990 monitoring program did not include these substances, apparently because of the lack of defined testing protocols.*

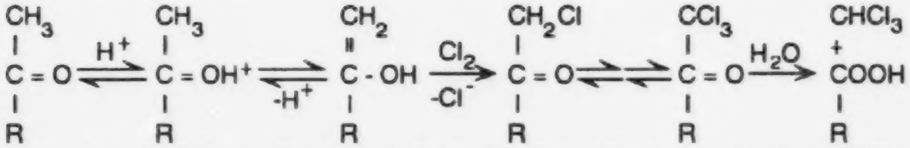
Chloroform intermediates are also formed in the C-stage, and chloroform is realized upon treatment with hypochlorite. If the intermediate compounds are only subjected to a neutral or basic pH environment, methylene chloride may be formed instead.

Meta-dihydroxylated aromatic compounds and several other hydroxy and carbonyl structures which may be formed from lignin are precursors for the formation of chloromethanes, chloroacetic acids and chloroacetones when reacted with chlorine in acidic media.

Alkaline Catalysis



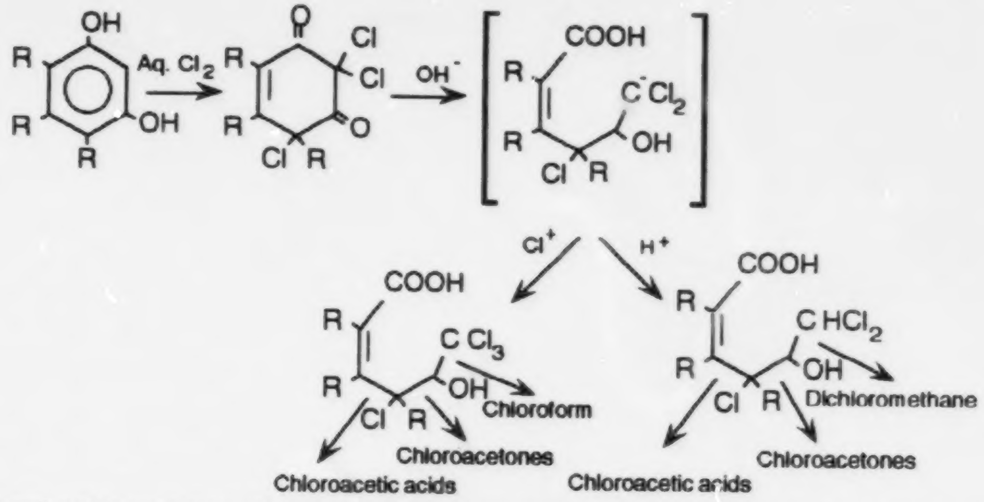
Acidic Catalysis



Most effective under alkaline condition (H-Stage), but can take place under acidic condition as well (C-stage)

Figure 27 The classical haloform reaction

The meta-substituted catechol-precursor may be formed by many reactions taking place in an acidic media containing elemental chlorine, i.e. C or C/D-stages. Thus, the elimination of the hypochlorite-stage of older bleach plants does not itself prevent chloroform formation, although the classic alkaline catalyzed haloform reaction in hypochlorite stages accounts for the greater fraction of chloroform. The CEHDED bleach sequence results in releases of chloroform of 240 to 300 g/ADt. In fact, levels exceeding 1,200 g/ADt have been reported by NCASI (Dallons 1990). In the case of Mönsterås, only 7 g/ADt of chloroform was reported in the untreated effluent, and this was eliminated during ASB treatment (<0.1 mg/ADt). A typical C_d E D E D bleach line has been reported to discharge 10 g/ADt of chloroform from the C_d stage, and 30 g/ADt from the E_1-stage (IPK 1982). This indicates the extent of the reduction in chloroform discharges when hypochlorite bleaching is eliminated.



Formation of chloromethanes, chloroacetic acids and chloroacetones in chlorine bleach plants with or without H-stages

Figure 28 Mechanism of formation of chloro-organics

The untreated effluent from Mönsterås contained around 9.5 g/ADt of 1,1-dichlorodimethylsulfone ($CHCl_2SO_2CH_3$), and this compound was only reduced to 6.5 g/ADt during treatment (30% reduction). Only very low levels of chloroacetones were found in the influent, and none in the effluent. Di- and tetrachlorinated acetic acids (~ 64 g/ADt) are virtually eliminated during biological treatment, but these levels are even significantly lower than previously reported values (300 to 1200 g/ADt) (IPK 1982) even before biological treatment. Chlorinated verathroles were not found in the effluent as could be suspected from the work of Nielson (Folke 1991).

4.7 Polychlorinated Dioxins and Furans (PCDD/PCDF)

SUMMARY The PCDD/PCDF compounds have been identified as a group of compounds with varying degrees of toxicity. 2,3,7,8-TCDD has been identified as the most toxic of this group and the toxicity of the others are related to TCDD in setting toxicity equivalent factors. The most important factors in minimizing the content appear to be low Kappa number prior to bleaching, low chlorine multiple, and high chlorine substitution. PCDD/PCDF are removed to some extent in biological treatment through adsorption in the sludge. Dechlorination takes place more readily under anaerobic conditions, i.e. in the sludge. The detection limit for TCDD/TCDF is reported to be 10 pg/L based on high resolution analysis.

The NCASI 23 mill study (Dallons 1990) states a detection limit for TCDD/TCDF of 10 pg/L based on their high resolution GC/MS procedure. This is a statistically based limit where data will still be normally distributed. It is possible to actually recognize TCDD/TCDFs at levels as low as a few pg/L, but it will be impossible to apply normal distribution statistics to the results, so for all practical purposes of this report, 10 pg/L is a usable limit of detection.

Various systems have been used to convert a multitude of PCDD/PCDF levels into a simpler expression, e.g. by the use of toxic equivalent factors. In the USA and Canada, the NATO-units system is used (refer to Table 17).

Table 17 Toxic equivalency factors for PCDD/PCDF

Homologue	NATO	Eadon	Nordic 1987	USEPA (1987)
Dioxins				
2,3,7,8-TCDD	1	1	1	1
All other TCDDs	0	0	0	0.01
1,2,3,7,8-PCDD		1	0.5	
2,3,7,8-substituted PCDDs	0.5			0.5
All other PCDDs	0	0	0	0.005
2,3,7,8-substituted HxCDDs	0.1	0.03	0.1	0.04
All other HxCDDs	0	0	0	0.0004
1,2,3,6,7,8-HpCDD		0	0.01	
2,3,7,8-substituted HpCDDs	0.01			0.001
All other HpCDDs	0	0	0	0.00001
OCDD	0.001	0	0.001	0
Furans				
2,3,7,8-TCDF	0.1	0.33	0.1	0.1
All other TCDFs	0	0	0	0.001
1,2,3,7,8-PCDF	0.05	0.33	0.01	0.1
2,3,4,7,8-PCDF	0.5	0.33	0.5	0.1
All other PCDFs	0	0	0	0.001
2,3,7,8-substituted HxCDFs	0.1	0.01	0.1	0.01
All other HxCDFs	0	0	0	0.0001
2,3,7,8-substituted HpCDFs	0.01	0	0.01	0.01
All other HpCDFs	0	0	0	0.00001
OCDF	0.001	0	0.001	0

Ontario is presently using the NATO toxicity equivalents.

The rationale behind these systems is that 2,3,7,8-TCDD is the most toxic of all the isomers, and that isomers with more chlorine atoms that have the 2,3,7,8-substitution pattern potentially degrade to 2,3,7,8-TCDD and are often more toxic than other isomers. The original Eadon and NATO toxicity emission equivalents have since been supplemented as new knowledge has emerged. Therefore, either the USEPA or the Nordic model will probably be used more by regulatory authorities in the future.

There is a critical difference between the Eadon and USEPA equivalency factors on the one hand, and the NATO and Nordic on the other. **The Octa-chlorinated dioxins and furans are considered to have zero toxic equivalents in former scales, but to be equivalent to 1/1000th of TCDD in the latter. The Octa homologues were the principal dioxins/furans found in the non-kraft mills in the 1990 MISA monitoring program.**

PCDD/PCDF appears to be formed entirely at the first C/D-stage (Dallons 1990). The actual amounts of PCDD/PCDF formed depend on the concentration of molecular chlorine in this stage and the concentration of DBD and DBF precursors in the brown stock. The chlorination factor appears to be the most important of the two. Hrutfiord and Negri (1990) found that compression wood was a likely source of unchlorinated DBD and DBF built into the lignin structure and chlorine side-chain displacement releases the PCDD/PCDFs.

Quantities discharged

US pulp mill effluents show contents of 2,3,7,8-TCDD ranging from the detection level around 1 to 500 μg/ADt. The most important factors in minimizing the content appear to be (1) low Kappa number prior to bleaching, (2) low chlorine multiple and (3) high chlorine dioxide substitution (Dallons 1990). While cautioning readers that the effects of any one process technology were not necessarily transportable to other mills, Dallons noted that the two mills which used oxygen delignification out of the 23 examined had the lowest emissions of TCDD.

Generally PCDD/PCDFs are reduced in biological treatment through adsorption to the sludge phase (Gillespie 1990). This is one reason why TSS control may be important. Furthermore, dechlorination of highly chlorinated organics takes place more easily under anaerobic conditions, i.e. in the sludge.

At the Mönsterås mill the levels of PCDD/PCDF were 0.41 μg/ADt (based on the EPA 1987 TEQs) or 1.3 μg/ADt (based on Nordic TEQ) equivalents in the untreated effluent. Refer to Table 17 on page 134 which presents various TEQ data. The effects of biological treatment are uncertain. In the first sampling significantly higher levels were found in the treated effluent, but this was not the case after a repeated sampling. Normally PCDD/PCDFs are associated with sludge, and poor TSS control may lead to unexpected high levels in the effluent. Whether or not this occurred has not been established.

2,3,7,8 TCDD was found in two Ontario mills in the first six months of MISA monitoring. James River, Marathon, had 9 and 13 μg/tonne in two samples, non-detect in the other four samples. Kimberly-Clark at Terrace Bay had 1.8 and 2.5 μg/tonne, with no detectable 2,3,7,8 TCDD in the four other tests in the period. This indicates that the nine mills in the Province discharge substantially less TCDD than the US mills. These relatively low discharges probably reflect the extensive efforts made by all mills since 1988 to reduce the formation of dioxin, rather than any geographical difference. The US data were based primarily on samples collected during 1988. It is well known that the dioxin control measures were mostly being initiated during that period across North America and Scandinavia, whereas all the "simple" measures were in place by early 1990, when the MISA monitoring commenced. Some additional dioxin control measures which necessitated significant capital investment, technical development or other actions requiring significant lead time were also operational by 1990.

In the USA a number of mill studies have been conducted. In 1986 the USEPA and the industry performed a cooperative 5 mill screening study (NCASI 1988b). 2,3,7,8-TCDD was found in seven of nine bleached pulps collected at those five mills ranging from 3 to 51 ppt, and 2,3,7,8-TCDF was found in eight of the nine bleached pulps at levels ranging from 8 to 330 ppt. Wastewater concentrations of 2,3,7,8-TCDD ranged in three of the five mills from 0.015 to 0.12 ppt, and 2,3,7,8-TCDF was found in four of the five mill effluents at levels from 0.011 to 2.2 ppt.

PCDD/PCDF was found to be more than 90% transferred to the sludge and suspended solids during wastewater treatment.

This study initiated another cooperate screening study to include all 104 bleach plants in the USA in 1988 (USEPA 1990). Results indicate that TCDD/TCDF concentrations in sludge and final pulp are more than 1000 times greater than treated effluent concentrations, and that there is a great variation in concentration between different mills. Also TCDF tends to be 50 to 100 times higher in concentration than TCDD. Extremes in sludge concentrations are 1,400 ppt (TCDD) and 17,000 (TCDF) down to 3 ppt (TCDD) and 50 (TCDF). Effluent concentrations range from 320 ppq (TCDD) and 4,000 (TCDF) to below detection limits (< 10 ppq).

2,3,7,8-TCDD, and PCDD/PCDF in general, leave the process by three paths, with pulp, with effluent to the receiving waters, and in effluent treatment plant sludges. The above mentioned 104 mill study demonstrated that partitioning is very roughly one-third via each path, but wide and unexplained variations were found.

Monitoring PCDD/PCDF

Monitoring PCDD/PCDFs in pulp mill effluents on a regular basis constitutes a challenge for the environmental regulators as well as mill operators. The chemical analysis by high resolution GC/MS of PCDD/PCDF is expensive and inaccurate for control purposes. The mechanisms of their formation from unchlorinated precursors is the same as the mechanism of formation of polychlorinated phenols (PoCPs). One possibility would therefore be to use the contents in an effluent of polychlorinated phenolics to indirectly measure the amounts of PCDD/PCDF, i.e use the sum of concentrations of tri- and/or tetrachlorophenolic compounds, such as phenols, guaiacols, catechols and trichlorinated syringols. The bleaching conditions, under which tetrachloroguaiacol is formed in the greatest amount, are similar to the bleaching conditions under which 2,3,7,8-TCDD is formed (Fleming 1990).

The rational basis for the conclusions regarding the chlorination factor is that each unchlorinated precursor molecule will have to meet at least four chlorine molecules in order to form a hazardous PCDD/PCDF molecule. If the chlorination factor is lowered then this event becomes rare. The same rationale may be used regarding the formation of tetrachloroguaiacol or tetraclorocatechol. Therefore, the PCDD/PCDF contents of wastewater have to be correlated to the content of tri- and/or tetrachlorophenolic compounds, such as guaiacols, catechols and trichlorinated syringols, although the exact correlations have to be studied further (Folke 1991).

Concentrations of PoCPs may well prove to correlate well with the highly-chlorinated proportion of AOX, and it could turn out to be the only parameter needed to control the discharge of environmentally significant; chlorinated organic matter from bleach pulp mills. Fast and reliable methods that may be standardized for their analysis using GC/ECD are within reach (Guerra 1988, NCASI 1988a).

4.8 Chlorinated Lipophilics

Chlorobenzenes are mainly used as dye carriers in the textile industry. Other uses include as an intermediate in herbicide manufacturing, dielectric fluid, heat transfer medium, degreasing agents, septic tanks, wood preservatives and abrasive formulations (hydraulic oil). Chlorobenzenes resist biological treatment unless especially adapted activated sludge is used, and they tend to accumulate in aquatic biota. In the atmosphere they are photochemically dechlorinated and degraded. Acute toxicity is moderate (EC_{50} for algae, and LC_{50} for fish is in the order of 0.5 to 5 mg/L for different species) (Landner 1989). Hexachlorobenzene has a number of different applications in organic synthesis. It is much more persistent and toxic than the lower homologues.

Except for a possible minor use as an abrasive agent there should be no obvious source of chlorobenzenes in pulp mill effluents. They are not formed by chlorination in the bleach plant. Therefore, chlorobenzenes are most effectively controlled at their source, i.e. the chemical industry.

Hexachlorobutadiene is, for instance, used as a solvent for rubber, in transformers, in hydraulic oil, and as a degreasing agent. It is widely distributed in the environment, it bioaccumulates and is quite toxic to aquatic life. However, biological treatment plants are normally able to degrade hexachlorobutadiene (Landner 1989).

Hexachlorocyclopentadiene is mainly used as a flame protection agent, but has other uses such as in the manufacturing of resins. It is potentially bioaccumulative and has a high acute toxicity towards fish, especially larvae. Its pathway to environmental degradation is abiotic photolysis rather than biological degradation. If subjected to biological treatment it will probably be associated with the sludge phase.

Minor amounts of chlorinated aromatics in pulp mill effluents are not from pulp bleaching, because it takes a very high chlorine pressure to chlorinate non-activated benzene rings[50]. Bleach plants operate at atmospheric pressure and are not capable of chlorinating aromatic benzene rings. However, chlorinated benzenes with one to six chlorines have been reported at levels of 10 to 100 mg/ADt (IPK 1982).

4.9 Metals

The data collected on metals concentrations in the mill effluents during the first six months of the 1990 effluent monitoring program are presented in the MOE report (MISA 1991). The maxima and averages for each sub-sector are presented in Table 18. Surprisingly high concentrations of zinc were reported for one mill, up to 9.3 mg/L. The company staff were unable to offer any explanation for this, but the authors are forced to question the validity of these data simply because it is unusual. However, there is no known reason to question the sampling or analytical procedure, so this remains a question to be investigated.

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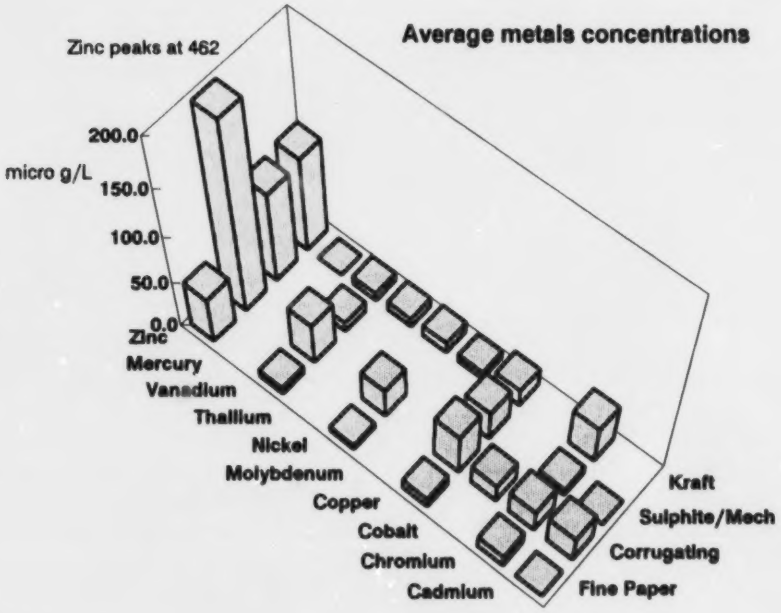
[50] *The OH group of phenolics increases the electron density of the aromatic ring making substitution with chlorine possible at atmospheric pressure. A chlorine substituent decreases the electron density slightly making it increasingly more difficult to add yet another chlorine substituent. Tetrachloroguaiacol can only be made in a bleach plant because there are two oxygen bound to the ring (and so has DBD precursors). Thus tetrachlorophenol in a pulp mill effluent originates with the use of raw materials contaminated with pentachlorophenol or some other source.*

Table 18 Metals concentrations in effluents

	Kraft		Sulphite/Mech		Corrugating		Fine Paper		Overall Industry	
Metal	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg
Aluminum	6,840	1,834	6,900	1,312	5,340	1,899	18,300	2,153	18,300	1,799
Cadmium			8	0.46	140	28	3	0.56	140	10
Chromium	300	40.6	84	7.2	68	23	182	12.0	300	21
Cobalt					70	19			70	19
Copper	290	18.8	290	31.5	140	44	35	9.9	290	26
Molybdenum	60	7.9							60	8
Nickel	160	11.1			100	31	25	4.9	160	16
Thallium	40	9.1							40	9.1
Vanadium	70	8.4	170	10.3	180	44	55	7.9	180	18
Mercury	3	0.1							3	0.1
Zinc	490	99	430	95	1631	462	9,290	49	9,290	176

All concentrations are expressed in μg/L Overall average is simple arithmetic mean of data shown, and is NOT weighted by mill or production.

The maximum concentrations of each metal found in each sub-sector are shown in Figure 30 and the average values reported in by MISA (1991) in Figure 29.

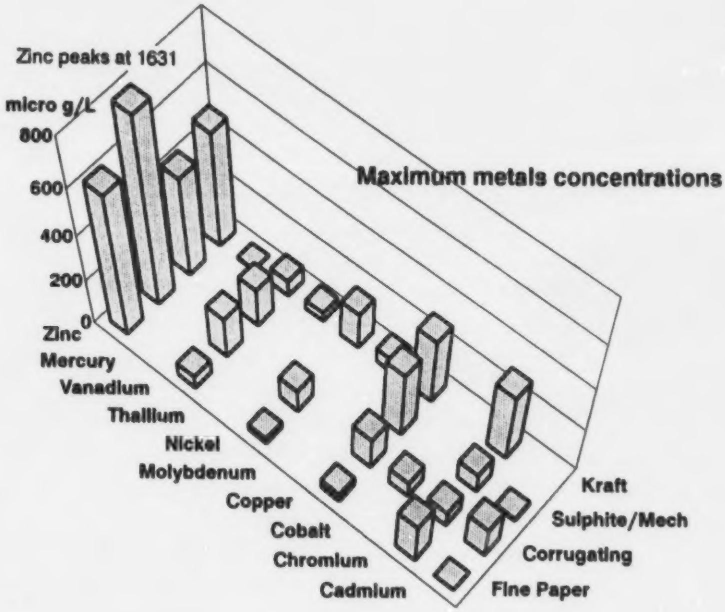


METALS.XLS Chart 2

Figure 29 Metals concentrations in effluents (averages)

Copper, zinc, mercury and cadmium are known constituents of wood, because growing trees accumulate these metals when exposed to them. Cadmium and mercury are by far the most significant priority pollutants. No analytical results on the influent to the mills were included with the MISA data. It is possible that some of these metals were present in the raw water.

Aluminium is used worldwide to reduce COD, AOX and toxicity of effluents (Folke 1991). When used, proper clarifier operation is important to minimize discharges, but aluminium is hardly a priority problem except in particularly vulnerable receiving waters. Aluminium becomes very toxic to aquatic life at low pH values, i.e. an effect of acid rain. Ferric chloride or polyelectrolytes could be alternative agents for chemical coagulation in some cases.



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Several data in the range 6000 to 9290 µg/L for zinc were reported to the Kimberly-Clark mill at St Catharines, and have been omitted from the graph, since subsequent testing showed concentrations consistently lower than 120 µg/L.

Figure 30 Metals concentrations in effluents (maxima)

Copper salts are generally used in wood protection, fungicides and toxic pigments in antifouling agents. Trace amounts of copper for use in co-enzymes are essential to all life, but in slightly higher amounts copper can be very toxic to fish and algae (Landner 1989). Copper tends to accumulate in phytoplankton, but to a smaller degree in higher organisms. In fish copper is accumulated in liver, gills and bones. We have not found any specific results in the removal of copper during biological treatment, but from the above result one may speculate that copper is concentrated to a certain extent in biosludge.

Mercury is used in older chlor-alkali plants and may be carried to the bleach plants by chlorine gas. Previously phenyl-mercury acetate was used for control of fungi in the pulp and paper industry. Today its main use is in batteries, electronic instruments and for dental purposes. Mercury is very bioaccumulating in its alkyl-mercury form (BCF > 100,000) and is very toxic to aquatic species, so exposure should be avoided. Although mercury can be concentrated in biosludge, it is most effectively controlled at the source, i.e. by closing chlor-alkali plants using mercury cells, by avoiding its use for dental purposes etc.

Zinc is the most widespread heavy metal in nature. High concentrations can be toxic, but low concentrations are essential to make proteins function. Its concentration in lakes depends on the acidity of the lake, and is thus connected to acid rain. The main source of zinc in pulp mill effluents is the wood. Zinc has a high acute toxicity to many species in laboratory testing. In nature this is seldom the case, because zinc is associated with humic materials and other organic matter and is hence non-bioavailable (SNV 1988). Furthermore, zinc is known to have an antagonistic effect on mercury and cadmium in fresh water lakes (Lindeström 1982). This means that the presence of zinc in the water body suppresses the accumulation and effects of mercury and cadmium. Therefore, one should be reluctant to reduce the discharge of zinc into water bodies that are contaminated with mercury and cadmium.

4.10 Data from the First 6 Months MISA Program

The conclusions in this report are, as much as possible, based on the characteristics of the Ontario mill effluents determined during the MISA monitoring program in 1990. The principal exceptions are as follows:

Only data collected during the January to June 1990 period were analysed, because of the need to comply with the MISA schedule requiring a draft of this report by May 31, 1991. The MISA monitoring program data had to be summarized and reviewed, and quality control procedures had to be implemented before the data became useful. The results of the first six months flow measurement, sampling and chemical analysis were not published until February 1991. The results of the first six months toxicity testing on trout and *Daphnia magna* were not available until the 18th of March 1991 (some preliminary data were made available by early March 1991).

The MISA first six month's of data were provided to the authors in raw electronic form, before summaries had been prepared, and without daily mill production data. Data on daily mill production were provided by MOE Thunder Bay office (for the NW region), OFIA for many mills, and by some mills directly. The authors processed the data to generate the summaries and discharge rates per tonne of product required for analysis of the best available technology options. Summary data are used in many ways in the report, and a comprehensive summary is presented in Appendix B.

Although it would have been desirable to have a full year of monitoring data for this report, time constraints made this impossible. The MISA data were of utmost importance to this project, and the authors found it necessary to undertake the processing of these data and to limit the analysis to the first six months of 1990 to be able to comply with the Ministry's schedule for completion of this report.

Where mills considered that data collected during the latter half of 1990 would differ from the earlier data, comments on the new data were considered. MOE scanned the data and provided a summary of the major differences, which were also considered by the authors.

Mill production data collected during the MISA program were limited to monthly averages, but since daily data, corresponding to the daily sampling, were necessary, they were collected by the authors from OFIA, from mill visits and from MOE files. Many minor inconsistencies in the production data from different sources, generally under 3%, were found and ignored, since the errors inherent in determining effluent characteristics are normally greater than this level. The production data were accepted as reported, without attempting to convert to a common moisture content, inclusion/exclusion of wrappers etc, since such factors will not cause errors above about 3%, which is insignificant relative to the normal effluent measurement errors.

Some parts of this report are based on production data from different, and inconsistent sources. The authors consider that the time required to resolve these inconsistencies to be unjustifiable, and have therefore used the data as received, except for elimination of obvious errors. There are significant inconsistencies in the production reported to the MISA database with respect to "market pulp" vs "bleached pulp produced", which the authors resolved to the extent possible. Some mills, such as Dryden, produce pulp for use on-site as well as for market, and also purchase kraft pulp from sister mills and on the open market. For engineering effluent discharge control systems, the kraft production rate in the mill is the most important, while regulators may be interested in other data.

4.10.1 Background

The municipal industrial strategy for abatement (MISA) program was initiated after the "St. Clair River Blob" in 1985 when heavier-than-water chemicals were found at the bottom of the river (MISA 1989, Turner 1989). This started the province-wide program of effluent limits which would apply to the major industrial dischargers and also to municipal sewage treatment plants. The goal of the MISA program is the "virtual elimination of persistent, toxic compounds from the waters of Ontario" and it covers nine industrial sectors including the pulp and paper industry.

The Ministry developed a list of chemicals known as the "Effluent Monitoring Priority Pollutant List" (EMPPL) from a screening list of 5000 chemicals associated with industrial operations. The list now contains 200 compounds, but as analytical protocols were developed for only about 135 of these compounds, those are the ones that industry was required to monitor (this list omitted certain pulp mill specific compounds such as chloroguaiacols or catechols).

The MISA monitoring program for the pulp and paper sector is summarized in Table 19. The sampling program was conducted throughout 1990.

In addition to the monitoring requirements summarized in Table 19, programs were defined and implemented for monitoring cooling water, waste disposal site effluents and backwash effluents. (Turner 1989). **These data are not considered in this report.**

All mills were required to monitor all process effluents and cooling waters for toxicity (rainbow trout and *Daphnia magna*) on a monthly basis. The frequency was reduced to a quarterly basis if the first three months of testing indicated no acute toxicity in all test dilutions.

Stringent QA/QC was imposed both on the flow measurement, sampling and the analyses, i.e. processing replicates, method blanks, spiked method blanks and spiked samples. Results were reported to the Ministry as hard copy as well as on a floppy disk.

Table 19 Process effluent streams monitored in 1990 MISA program

Variable	Reporting frequency	Variable	Reporting frequency
All Mills:		**Kraft pulp, additionally:**	
COD	Daily	Dehydroabietic Acid	Thrice weekly
BOD	Thrice weekly	AOX	Thrice weekly
pH	Daily	Dichlorodehydroabietic Acid	Thrice weekly
NH_3-N	Monthly	Sulphide PCDD/PCDF	
Tot-N	Monthly	**Bleached pulp mills, additionally:**	
$NO_2^- + NO_3^-$	Monthly	PCDD/PCDF	Bi-monthly
DOC[1]	Daily		
Tot-P	Monthly	**Sulphite-mechanical and**	
Spec. cond.	Daily	**corrugating mills, additionally:**	
TSS	Daily	Dehydroabietic Acid	Thrice weekly
Aluminium (Al)	Weekly		
Zinc (Zn)	Weekly	**Deinking, board, fine papers, tissue**	
Other metals[2]	Monthly	**tissue, additionally:**	
Halogenated volatiles[3]	Monthly	AOX	Monthly
Non-halogenated volatiles[4]	Monthly	PCDD/PCDF	Monthly
Base-Neutral Extractables[5]	Monthly		
Acid extractables[6]	Monthly	**Mills operating biological treatment**	
Chlorinated extractables[7]	Monthly	**plants, process effluents:**	
Fatty and resin Acids[8]	Monthly	NH_3-N	Weekly
PCDD/PCDF	Semi-annual	Tot-N	Weekly
PCBs	Semi-annual	$NO_2^- + NO_3^-$	Weekly
Open characterization[9]	Semi-annual	Tot-P	Weekly

Source: Turner 1989

[1] dissolved organic carbon

[2] Ag, Be, Cd, Cr, Co, Cu, Hg, Mo, Ni, Pb, Tl, V

[3] 26 aliphatic compounds

[4] benzenes, styrene, toluene, xylenes

[5] 24 compounds, mainly polyaromatic

[6] 20 compounds mainly (chloro)phenols, hydrocarbons, cresols, and nitrophenols, but none of the typical wood phenolics such as guaiacols, catechols etc.

[7] 12 compounds mainly benzene types

[8] abietic, chlorohydroabietic, dehydroabietic, isopimaric, levopimaric, neoabietic, oleic and pimaric acids

[9] volatile and extractable organic compounds

4.11 Kraft Mill Discharges

The analytical data referred to in the following discussion are taken from Appendix B. The alternative technology trains referred to for reduction of pollutants at source are described in Chapter 7.

General comments

The COD/BOD ratio in untreated wastewaters would be around 3 to 4. The COD discharge of a bleached kraft mill using conventional bleaching would be about 100 to 150 kg/tonne.

2,4-dichlorophenol has been reported to be substantially reduced in biological treatment. Chlorophenols would be reduced somewhat by train K2 and more so by trains K3, K4 and K5.

4.11.1 Boise Cascade Canada Ltd., Fort Frances (Mill 06)

This mill produces 680 tonnes per day of groundwood specialty paper and 575 tonnes per day of bleached market pulp. Turpentine and tall oil are recovered. Effluent treatment consists of primary clarification of wood room and paper mill effluent and treatment of the total effluent in two parallel settling ponds and 5 days retention in an ASB.

The BOD is around 10 kg/tonne and COD/BOD is 6; normal figures after a modest degree of biological treatment. TSS is above 10 kg/tonne which is quite high for a biologically treated waste[51].

Trichloromethane (chloroform) emissions are in the order of 30 to 90 g/tonne; as expected from a bleach operation involving an H-stage (C/D E_0H D). The presence of 2,4-dichlorophenol and 2,4,6-trichlorophenol is expected from normal chlorination reactions, but 2,3,5-trichlorophenol and the chlorinated aromatics probably originate from non-bleaching sources such as cleaning solvents or forest herbicides. All the alternative technology trains for kraft mills would substantially eliminate the chloroform emissions and reduce TCDF below detectable concentrations.

The presence of TCDF and absence of TCDD is in accordance with previous findings.

Resin acids are normally in the range 10 to 100 g/tonne product. In one sample from January the figure for total resin acids was reported as 5,985 g/tonne which is obviously an error. However, that figure is associated with increased levels of BOD and COD indicating possible spills.

AOX figures around 4 to 5 kg/tonne of bleached pulp are typical for the mill process configuration. These would be lowered by various degrees by the alternative technology trains.

The relatively high conductivity indicates that projects to reduce the effluent flow substantially may encounter difficulties with excessive inorganic salt concentrations.

4.11.2 Canadian Pacific Forest Products Ltd., Dryden (Mill 08)

This mill produces 735 ADt per day of bleached kraft pulp; some is sold directly and the remainder used on site for fine paper production. Most of the pulp produced is softwood, and the mill also purchases some hardwood kraft pulp. The pulp is bleached according to the sequence (C/D E_0 H D E D). Effluent treatment consists of primary clarification followed by ASB with 5 days retention time.

BOD is around 3 kg/tonne and COD/BOD is about 17 indicating efficient BOD removal. The remaining COD is therefore quite persistent. There is considerable variation in COD from day to day, which may be due to erroneous production data, or to erratic operation. The effluent was consistently non-lethal to Daphnia magna, but marginally lethal to trout during the first six months of the 1990 MISA monitoring program. TSS control is quite good with figures around 5 to 6 kg/tonne.

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[51] *Mill staff have advised that the TSS discharge was reduced to approximately 5 kg/tone in late 1990 by dredging the ASB quiescent zone.*

The first 6 months data indicate chloroform, 8 to 23 g/tonne, which has not been stripped in the biological treatment system. These levels are higher than normally found in a biologically treated effluent. There appears to be some seasonal correlation, with lower chloroform discharges in summer than winter. Di- and trichlorophenols are also found indicating a non-analysed presence of chlorinated guaiacols and catechols as well.

Minor amounts of chlorinated aromatics are of unknown origin, not from pulp bleaching *per se*. In three samples an average of 11 µg/tonne of total TCDF was found - no TCDD. Defoaming agents have been identified as potential precursors for PCDFs.

Resin acid discharges are, 20 g/tonne after biological treatment effluent, in the same order of magnitude as for the untreated effluent from the Mönsterås bleached kraft mill discussed in Appendix C (14 g/ADt). Technology trains K1 and K2 will have little effect on these discharges because Dryden already uses biological treatment. Trains K3, 4 and 5 can be expected to reduce resin acid discharges below 1 g/tonne.

AOX discharges are 2 to 4 kg/tonne. These remaining organochlorines can be considered to be quite persistent, because they have already passed through a biological treatment plant. A water use of 95 m^3/tonne is a little below average, as can be seen from the relatively high conductivity.

4.11.3 Canadian Pacific Forest Products Ltd., Thunder Bay (Mill 09)

This mill produces 1320 tonnes per day of semi-bleached and fully bleached market pulp. In addition to this, it produces 910 tonnes of groundwood and, while the MISA monitoring program was in progress, about 300 tonnes of high-yield sulphite pulp per day for newsprint production[52]. Softwood and hardwood are bleached in one of two bleach lines (C/D) E H D E D or (C/D) E_O D E D). Groundwood is brightened by sodium hydrosulphite. Effluent treatment consists of primary clarification.

The BOD load of around 22 kg/tonne and a COD/BOD ratio of 3.5 are as would be expected from this type of operation. The TSS discharges are 7 to 9 kg/tonne.

Considering that only one of the two kraft pulp bleaching lines has an H-stage, the chloroform discharge of 200 to 300 g/bleached tonne is surprising because it is in the high end of the range reported for US mills (Dallons 1990). Some of this chloroform will be stripped from the effluent in the oxygen activated sludge system currently under construction. Technology trains K1 and K2 would reduce chloroform. Trains K3, K4 and K5 would be more effective.

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[52] *The high yield sulphite mill was shut down in early 1991.*

Di- and trichlorophenols are also found indicating the probable presence of chlorinated guiacols and catechols as well[53]. 2,3,5-trichlorophenol is not readily formed from direct chlorination of phenol. Minor amounts of chlorinated aromatics are also found.

Resin acids loads are 570 g/tonne, with peaks at 1500 g/tonne. The relatively high values are perhaps due to the high-yield sulphite mill which has since been shut down, but are in part expected from a groundwood operation. Probably, the presence of unchlorinated phenol is from the unbleached sulphite operation. There is no evidence that black liquor spills occur from the kraft operation, because the peaks of resin acids may well arise from spills of sulphite liquor.

AOX discharges are 3 to 4 kg/tonne. About 40% of the material is probably readily degraded, because it has not yet passed biological treatment.

Conductivity measurements indicate that a water savings program at the mill could be effective, even though a water use of 80 m^3/tonne is not in the high end of the normal range.

4.11.4 Domtar Inc., Fine Papers Div., Cornwall (Mill 10)

This mill produces 410 tonnes per day of fully bleached hardwood pulp and 750 tonnes/day of fine paper are produced. Kraft pulp is purchased. Bleaching of hardwood kraft is carried out in a bleach line corresponding to $(D_{45}C_{55})\ E_O$ D E D. Effluent treatment consists of primary clarification.

The BOD is around 30 kg/tonne and COD is 90 to 100 kg/tonne. This is quite high even considering that no biological effluent treatment is applied, and it indicates a loss of black liquor to the sewer. A COD/BOD ratio of around 3 is quite normal. TSS is 15 kg/tonne which is high considering that there is a primary treatment system. This could be due to poor fibre and/or filler loss control on the paper machines or fibre loss on the brown stock decker.

Chloroform is about 40 g/ADt, which is higher than expected with this kind of bleach line. The presence of benzene, alkyl substituted benzenes and PAH in the effluent indicates a possible leak of gasoline, light oil or similar material.

Di- and trichlorophenols are not found. Because hardwood is used this cannot be taken as an indication of the lack of chlorinated phenolics in the effluent. Hardwood species tend to produce lignin from more substituted precursors, so that chlorinated syringols (2,6-dimethoxyphenol) can be found in these effluents.

Resin acids loads are high, 130 g/ADt. This is presumably due to rosin size from paper making. Unchlorinated phenolics are not found, perhaps because the MISA monitoring program did not analyses for the expected types.

AOX is slightly over 1 kg/ADt. Part of this material will be readily degraded biologically, since it has not passed through biological treatment.

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[53] *The 1990 MISA monitoring program did not include guiacols and catechols.*

Conductivity measurements are rather difficult to interpret, because the mill includes a fine paper operation. The water consumption approaching 180 m^3/tonne is very high, and water savings should be attainable.

4.11.5 Domtar Inc., Containerboard Division, Red Rock (Mill 11)

This mill produces approximately 760 tonnes per day of unbleached kraft pulp and 140 tonnes per day of groundwood pulp to make 200 tonnes per day of newsprint and 700 tonnes per day of linerboard. Approximately 60 tonnes of softwood pulp is semi-bleached using a C E H bleaching sequence. Groundwood is brightened by sodium hydrosulphite.

It is difficult to draw useful comparisons of this mill with others, because it is unique in Ontario, and perhaps in North America. Only a small proportion of the kraft pulp is bleached. Technically, it is a bleached kraft mill, but the effluent characteristics are liable to be dominated by the unbleached kraft fraction. The relatively small groundwood mill also complicates analysis of the effluent data. As indicated in Chapters 7 and 8, the technologies considered as BAT for the kraft sector cannot all be applied to this mill, and where they can, the costs are relatively high for the reduction of AOX, since this is a bleach plant related contaminant.

Effluent treatment consists of primary clarification.

Considering the lack of a biological treatment plant the BOD figure of less than 20 kg/ADt is low, indicating good control of black liquor losses. The COD/BOD ratio of less than three indicates that the COD (around 50 kg/tonne) is partly degradable. TSS is approximately 8 kg/tonne.

The H-stage gives rise to chloroform, 10 to 25 g/ADt of pulp.

Octachlorodibenzo-p-dioxin was found, but the origin is unknown.

The fact that dichlorodehydroabietic acid is present in the effluent, but not monochlorodehydroabietic acid would normally indicate a high chlorination ratio at the C-stage. However mill data indicates that the Kappa factor was under 0.16, which is relatively low, and is below the level at which 2,3,7,8 TCDD would normally be found. The absence of TCDD and TCDF in the reported data (MISA 1991) confirms a low chlorination ratio.

Levels of resin acids are generally higher than for kraft operations due to the groundwood production, and some of the maximum values are unexpectedly high (<1100 g/tonne).

4.11.6 E.B. Eddy Forest Products Ltd., Espanola (Mill 14)

This mill produces 940 tonnes per day of bleached kraft market pulp of which about 160 tonnes per day is for integrated paper production. Turpentine and tall oil are sold as by-products. The mill has two distinct bleach lines, one for softwood with continuous digestion followed by O C_{44}/D_{56} E_O H D and one for hardwood with batch cooking followed by O C_{76}/D_{24} E H D. Effluent treatment consists of primary sedimentation and an aerated stabilization basin with 22 aerators.

The BOD is less than 2 kg/tonne and DOC is about 11 kg/tonne with a couple of peaks when production is down, perhaps due to the time lag between production and effluent discharge due to several days retention in the treatment system. TSS is around 2 to 3 kg/tonne.

The existence of the H-stage in the bleach plant hardly shows up in the low levels of di- and trichloromethanes (2 to 4 g/ADt of chloroform). These levels are almost the same as could be expected for a normal chlorination stage. The AOX figure around 1 kg/ADt must be made of fairly persistent compounds, because the BOD is so low and the DOC/AOX ratio is around 15. Trichlorophenol was found in minor amounts, again implying a presence of non-analysed, lignin related chlorophenols.

Resin acids are low indicating good spill control.

4.11.7 James River-Marathon Ltd. (Mill 16)

433 tonnes per day of fully bleached market pulp (92% softwood) are produced at this mill using batch cooking and the bleach sequence: C/D E_O H E D. (This was modified to cD E_O D E D from May 1991, and is normally operated without any chlorine in the first bleaching stage). Effluent treatment consists of primary clarification.

COD values exceed 100 kg/ADt and the BOD measurements of approximately 30 kg/ADt give a COD/BOD ratio of 3.8 which is as expected when no biological treatment has been applied. TSS is around 6 kg/tonne .

The normal AOX is around 5 to 6 kg/ADt for this mill. The monthly average in May of 3.2 kg/Adt is unusually low and due to anomalies in the bleached production, and thus, not typical for the mill. Extremely high levels of AOX were reported for several days in June 1990. An explanation has been offered that this was perhaps due to a problem with a new chlorine dioxide generator causing a discharge of chlorine dioxide to the sewer. However a simple mass balance shows that such high AOX discharges are impossible from any mill. To generate the 55 to 62 kg/tonne of AOX as reported would have required that over 50 tonnes/day of chlorine dioxide be discharged to sewer for several days, **and** that it would all react with organic matter to form organochlorines. The Marathon[54] mill would not be capable of generating such an amount. If it had discharged sufficient chlorine to the sewers, to generate over 2,500 kg AOX/day, there would have been a spectacular gas emission emergency. The authors are advised that the laboratory testing the samples had to dilute them considerably, suggesting that the reason for the bizarre data lies in sampling/analysis.

These aberrant values skew the average reported AOX discharge reported for this mill. If they are rejected, then the average discharge for the first six months of 1990 would be approximately half that reported by MISA (1991). The authors used 7.2 kg/tonne bleached pulp as the best available estimate of the AOX discharges from this mill wherever calculations were required for this report (Information received subsequently indicates that actual values in 1990 were somewhat lower).

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[54] *The authors are not aware of any North American mill that carries sufficient inventory of chlorine and chlorine compounds to be able to discharge the quantities of AOX reported for Marathon.*

While the MISA monitoring program was being conducted, the mill used a rather obsolete bleaching sequence, and the bleach plant equipment was in less than ideal condition. Since early 1991, the bleaching operation uses the above mentioned sequence, with high or 100% substitution in the C_d-stage, generally as defined in alternative technology trains K1 and K2 on page 241. This will reduce AOX discharges substantially. (May and June 1991 data received from the mill staff indicate approximately 2 kg/tonne).

Surprisingly, no lignin related chlorophenols were reported (di- and tri-chlorophenols) as could be expected from the presence of TCDD/TCDF's. Total TCDD discharges were 10 to 20 μg/ADt and total PCDF was around 200 μg/ADt.

The high levels of resin acids indicate relatively high black liquor losses. Conductivity (2000 μs/cm) and water consumption (130 m^3/tonne) show that water savings should be possible.

4.11.8 Kimberly-Clark Canada Inc., Terrace Bay (Mill 19)

This mill produces 1140 tonnes per day of bleached market kraft pulp, two thirds of which is produced from softwood. Batch digesters are used together with a bleach line of C/D E D E D for hardwood and of C/D N E_O D E D for softwood (N = neutralization). A recently constructed ASB is providing efficient biological treatment.

The low BOD of 1 kg/ADt indicates that the COD around 45 kg/tonne and the AOX of 1 to 2 kg/ADt are fairly persistent (COD/BOD ~50). TSS is 3 to 4 kg/tonne which is quite low for an ASB treatment system.

Minor amounts of chloroform are found (1 g/ADt). Both di- and trichlorophenol were found together with PCDD/PCDFs compounds arising from the bleach plant.

Resin acids are low, indicating a good spill control system and efficient biological treatment. Conductivity and water consumption indicate possible water savings.

4.11.9 Malette Kraft Pulp and Paper Co., Smooth Rock Falls (Mill 21)

This mill produces 340 tonnes per day of bleached market kraft pulp using batch cooking and a C_{84}/D_{16} E_O D E D bleach sequence. The effluent is treated in a primary clarifier.

The COD shows a huge variation - 25 to 200 kg/ADt - much higher than the variation of BOD 25 to 40 kg/ADt. The COD variation is not be due to poor fibre control, because TSS is fairly constant, about 5 kg/tonne. This wide variation in the COD/BOD ratio, probably indicates errors in some of the reported BOD or COD values, which make it difficult to assess the environmental quality of the operations.

Chloroform is moderately high, 15 g/ADt, corresponding to the presence of 2,4-di- and 2,4,6-trichlorophenol and an AOX level of 4 kg/ADt when no H-stage is applied. Levels of styrene, toluene, unchlorinated (not lignin-related) phenolics etc. could indicate poor spills containment, but these reported data do not correlate with the COD variations.

Resin acids are quite high too, indicating a possible overload on the kraft chemical recovery system. The water consumption is very high for a market pulp operation, 170 m³/tonne, and conductivity is low, so water savings are possible. (A new recovery system was under construction in early 1991).

4.12 Sulphite-Mechanical Mills

4.12.1 Abitibi-Price Inc., Thunder Bay Div. (Mill 04)

This mill produces 120 tonnes per day of sulphite pulp and 300 tonnes per day of groundwood pulp and makes 460 tonnes per day of newsprint with a small addition of market bleached pulp for strength. Effluent treatment consists of primary clarification.

The BOD load is around 60 kg/ADt, DOC is 60 kg/tonne and the TSS load is 4 kg/ADt. The origin of di- and trichloromethane remains obscure. Resin acids are fairly high (500 g/ADt) which is normal for a groundwood operation. Water consumption is high (95 m³/tonne) and conductivity is low, indicating a potential for water savings.

4.12.2 Abitibi-Price Inc., Fort William Div. (Mill 02)

This mill produces 135 tonnes per day of chemi-mechanical (sodium base sulphite) pulp and 210 tonnes per day of groundwood pulp for 390 tonnes per day of newsprint with a small addition of market bleached pulp for strength. Effluent treatment consists of primary clarification and settling basins.

The BOD load is around 40 kg/tonne, DOC is 27 kg/tonne, and the TSS load is 3 kg/tonne. The origin of phenol and cresols is uncertain. Resin acids are quite high (750 g/ADt), which is probably due to the combination of groundwood and SCMP production, which is somewhat similar to a CTMP operation. CTMP production based on softwood is known to cause high loads of resin acids. The water consumption is about 65 m³/tonne, and conductivity is 900 μs/cm, a reasonably tight water consumption for a newsprint mill.

4.12.3 Abitibi-Price Inc., Iroquois Falls Div. (Mill 01)

This mill produces 850 tonnes per day of standard and specialty newsprint from sulphite and groundwood pulp manufactured on site. Nominal capacities of the pulp mills are 240 and 540 tonnes/day respectively. Effluent treatment consists of two primary clarifiers in parallel with 4 hours nominal retention time.

The BOD load is around 70 kg/tonne, DOC is 60 kg/tonne, and TSS is 10 kg/tonne. The effluent contains some di- and trichloromethane, and in one sample in April, the whole range of halogenated volatiles was present. This is surprising. Some volatile aromatics were found frequently (toluene, phenol etc.).

Resin acids are quite high (800 g/ADt) as is normally seen for this type of mill. The water flow is 70 m³/tonne, and conductivity is 1100 μs/cm which is reasonably tight.

4.12.4 Abitibi-Price Inc., Provincial Papers Div. (Mill 03)

This mill produces 420 tonnes per day fine coated paper from its own production of groundwood (up to about 140 tonnes/day) and purchased market kraft pulp. Effluent treatment consists of primary clarification followed by a settling pond with 10 hours retention time.

BOD is as expected from a mill without secondary treatment, about 10 kg/tonne and DOC is 7 kg/tonne. TSS figures are low, 3.5 kg/tonne. TSS and DOC seem to follow the same pattern. This is a little unexpected, because the DOC analysis excludes fibres, and it suggests that the primary treatment system generally works well. The TSS load apparently comes from the pulp and paper mill production, not from an improper primary treatment system.

Dichloromethane (methylene chloride) and trichloromethane (chloroform) are in the order of 0.5 to 2 g/tonne, which is as low as expected from a chlorine compound free bleach plant operation.

Non-chlorinated resin acids are low in this effluent (~50 g/tonne). The water consumption per tonne of produced product is quite high, 110 m^3/tonne and conductivity is low 350 μs/cm, suggesting that the potential for effluent flow reduction is good.

4.12.5 Boise Cascade Canada Ltd., Kenora (Mill 07)

This mill produces approximately 850 tonnes per day of newsprint from 260 tonnes per day sulphite and 550 tonnes per day groundwood pulp with some purchased kraft pulp. Effluent treatment consists of primary clarification.

The BOD load is around 40 kg/tonne, COD is 110 kg/tonne, and TSS is 4 kg/tonne. The effluent contains some trichloromethane (chloroform) and phenol. Resin acids vary widely (from 200 to 3000 g/ADt), and this is unusual even for a newsprint mill. The water consumption is quite low, 50 m^3/tonne.

4.12.6 Quebec and Ontario Paper Company Ltd. (Mill 23)

This mill produces 870 tonnes per day of newsprint from an approximately equal mix of thermomechanical pulp and deinked pulp. Effluent treatment consists of primary clarification and oxygen activated sludge treatment.

The BOD load is around 1.5 kg/tonne, DOC is 2.0 and TSS is around 3 kg/tonne. This is low, and resin acids are also low at 1 g/tonne. The effluent passed all acute lethality tests in 1990 (8 each for *Daphnia magna* and for trout). This is a marked contrast from the other newsprint mills, and is presumably due to Q & O being the only mill in this sub-sector with secondary treatment.

4.12.7 St. Marys Paper Inc., Sault Ste Marie (Mill 24)

This mill produces 500 tonnes per day of super-calendered (SC) and machine-finished (MF) groundwood specialty paper with 20% bleached kraft and 10% fillers. The groundwood pulp production on site is approximately 400 tonnes per day. Effluent treatment consists of primary clarification.

The BOD load is around 15 kg/tonne of product. In two periods, in March and April, the BOD load was reported to be 5 kg/tonne, but this was not followed by a decline in COD, so the validity of these results is questionable[55]. TSS is in the range of 10 to 15 kg/day, and COD is around 50 kg/tonne. The reporting of chlorinated methanes was unexpected. Small amounts of naphthalene, phenol and cresols were also reported. Resin acids were around 400 g/tonne or 5 mg/L, which is probably the reason for the acute toxicity of the effluent. The water consumption is around 65 m^3/tonne and conductivity is low, 250 μs/cm, so water savings should be possible.

4.12.8 Spruce Falls Power and Paper Company Ltd., Kapuskasing (Mill 25)

This is a 1000 tonnes per day newsprint mill based on magnefite pulp, groundwood and thermomechanical pulp. The magnefite operation includes a chemical recovery plant. Some purchased kraft is also added. Effluent treatment consists of primary clarification.

The BOD load is 30 to 35 kg/tonne, and TSS is about 8 kg/tonne. COD varies by a factor of two from 50 to 100 kg/tonne, which is not reflected in the BOD value. Low levels of chloroform from an unknown source were also reported. Resin acids range from 400 to 600 g/tonne (4 to 9 mg/L). The water consumption is around 80 m^3/tonne, and conductivity is low, 300 μs/cm, so water savings should be possible.

4.13 Corrugating Mills

4.13.1 Domtar Inc., Containerboard Division, Trenton (Mill 13)

This mill produces 340 tonnes per day of corrugating medium from secondary fibres and 200 tonnes per day of semichemical soda pulp (hardwood). The white water system is quite closed, and the cooking liquor from the pulping process is recovered and used as a road binder.

The BOD load is around 15 kg/tonne, COD is 32 kg/tonne, and TSS is 1 kg/tonne. Resin acids were reported around 15 g/tonne. The water consumption is about 12 m^3/tonne, and conductivity is 1000 μs/cm.

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[55] *Mill staff have subsequently advised that the exceptionally low BOD data are questionable.*

4.13.2 MacMillan Bloedel Ltd., Sturgeon Falls (Mill 20)

This mill manufactures true NSSC pulp for use as corrugating medium (192 tonnes per day) and TMP for outdoor hardboard (variable production averaging about 70 tonnes per day). An anaerobic treatment system was commissioned in late 1990, and is not yet fully operational.

The BOD and DOC loads are 125 kg/tonne, and TSS is 8 kg/tonne. Total resin acids are 100 g/tonne.

The water consumption is 50 m^3/tonne, and conductivity is rather high, 1800 μs/cm, so further water savings may not be achievable without corrosion problems, or removal of the spent cooking liquor from the system.

4.14 Deinking-Board-Fine Papers-Tissue Mills

4.14.1 Beaver Wood Fibre Company Ltd., Thorold (Mill 05)

260 tonnes per day of paperboard, primarily for gypsum wall board, are made from secondary fibres. Effluent treatment involves primary clarification.

The resulting BOD load is around 8 kg/tonne, and TSS 4 kg/tonne with slightly higher values for both variables during winter. Trace amounts of some halogenated volatiles and of phenol are also reported, of insignificant environmental relevance. Resin acids vary from 20 to 50 g/tonne. Water consumption varies from 50 to 100 m^3/tonne, and conductivity is around 375 μs/cm, so water savings are possible. The production is quite unstable with shutdowns every week.

4.14.2 Domtar Inc., Fine Papers Div., St Catharines (Mill 12)

200 tonnes per day of fine and specialty paper are produced from bleached and semi-bleached market pulp and better qualities of secondary fibres. Effluent treatment consists of primary clarification.

The BOD load is generally below 10 kg/tonne, and TSS is 3 kg/tonne. COD values vary from 40 to 200 kg/tonne, which is inconsistent with the BOD load. Resin acids vary from 20 to 200 g/tonne, but these peak values are not correlated to the COD peak values. This raises the question as to the quality of the data. Water consumption is around 65 m^3/tonne, and conductivity is 375 μs/cm. This is a surprisingly high water consumption and pollution burden for a non-integrated paper mill.

4.14.3 E.B. Eddy Forest Products Ltd., Ottawa (Mill 15)

150 tonnes per day of fine papers are produced from purchased bleached softwood and hardwood pulp. Effluent treatment consists of primary clarification.

The BOD load is 7 kg/tonne, TSS is 2 to 3 kg/tonne, and the COD is around 15 kg/tonne. Trace amounts of halogenated and non-halogenated volatiles were reported including chloroform, benzene, toluene, xylene, and naphthalene. Resin acids vary from 3 to 50 g/tonne. Water consumption is around 45 m^3/tonne, and conductivity is 300 μs/cm, so water savings are possible.

4.14.4 Noranda Forest Inc., Recycled Papers, Thorold (Mill 22)

270 tonnes per day of fine paper are produced from purchased bleached kraft and deinked fine papers. The ink washer effluent is biologically treated in a separate system, before it is combined with the rest of the process water. The deinked pulp is bleached in a C or H sequence, and the effluent is combined with the process water. All process water goes through primary clarification prior to discharge together with the storm water effluent.

The BOD load varies from 8 to 15 kg/tonne, and DOC is 6.5 kg/tonne. There could be errors in the low values reported from January and February, because DOC values do not show a similar minimum. TSS had not been reported. AOX is generally low, 0.1 to 0.2 kg/tonne, although a peak value of 1.5 kg/tonne was reported for May 90. The H-stage gives rise to chloroform loads up to 16 g/tonne and 0.5g/tonne of bromodichloromethane. Hexachlorocyclopentadiene was reported in amounts of 10 to 30 mg/tonne. Resin acids are found in the form of dehydroabietic acid 40 to 50 g/tonne, and a variety of metals in trace amounts were found as well (possibly from the ink). Water consumption is around 75 m^3/tonne, and conductivity is 900 μs/cm, so water savings seem possible.

4.14.5 Kimberly-Clark Canada Inc., St. Catharines (Mill 18)

This is a converting paper mill producing 13 tonnes per day of glazed paper, 47 tonnes per day of wet crepe tissue paper and 64 tonnes per day of crepe tissue paper; all from purchased kraft pulp and secondary fibres. The effluent is treated in a primary clarifier.

The BOD load is around 3 kg/tonne, and TSS is less than 1 kg/tonne. COD shows great variations from 5 to 16 kg/tonne with the average around 9 kg/tonne. Resin acids are generally lower than 1 g/tonne, but occasional peaks of dehydroabietic acid are seen (in one example up to 26 g/tonne). These peaks are not correlated with BOD. The water consumption is high, 70 m^3/tonne, and conductivity is low, 400 μs/cm, indicating water savings are possible.

Several of the analyses conducted during the 1990 MISA monitoring program showed exceptionally high zinc concentrations. Two were rejected as being analytical errors after the likelihood of contamination from the sample bottle cap was established. Of the remaining samples, the highest was 9290 μg/L, whereas the highest concentration of zinc found in any other mill in this sub-sector was under 600 μg/L. The mill staff were unable to correlate the incidences of high zinc concentrations with any product grade, chemical used or other operating condition. (Personal communications with Dixon Ng, mill environmental engineer May and June 1991). In 1991 the company instituted a program of frequent analysis of the effluent for zinc in an attempt to establish if the discharges are actually so high, and if so to determine a means of eliminating them.

The authors of the present report have assumed that the high values are erroneous, since they are far beyond any other known data, and there have been no reports of any effects of zinc downstream. In the event that the current program determines that the emissions did actually take place, the solution will almost certainly be to eliminate the use of whatever raw material is the source.

4.14.6 Kimberly-Clark Canada Inc., Huntsville (Mill 17)

100 tonnes per day of facial tissue/household towels are produced from purchased bleached softwood and hardwood pulp. Effluent treatment consists of primary clarification for 14 hours and 5 days in a polishing basin. In the winter time, this is followed by tertiary treatment in percolation beds, and in the summer, the effluent is spray irrigated on the mill property, i.e. zero effluent.

In the winter time, the BOD load is generally below 0.03 kg/tonne, COD is less than 0.7 kg/tonne.

4.14.7 Trent Valley, Paperboard Industries Corporation, Trenton (Mill 27)

This mill produces 320 tonnes per day of uncoated paperboard from waste paper. Effluent treatment consists of primary clarification.

The BOD is about 5 kg/tonne, COD is 11 kg/tonne, and TSS is 1.8 kg/tonne. The water consumption is only 12 m^3/tonne. Conductivity is around 1000 μs, indicating that some further water conservation is possible.

4.14.8 Strathcona Paper Company, Napanee (Mill 26)

165 tonnes per day of boxboard are produced from secondary fibres. The paper machine is equipped with a saveall and two-thirds of the white water is reused. Effluent treatment consists of primary clarification followed by ASB and 3 facultative lagoons.

The BOD load varies from 1 to 6 kg/tonne, and TSS is around 1.5 kg/tonne. The COD/BOD ratio is roughly 3 except for very small BOD (faulty BOD results?) when the ratio approaches 7. Trace amounts of chloroform and other halomethanes are reported together with toluene, phenol, and cresols. Resin acids are generally small loads of 5 g/tonne or less, mainly dehydroabietic acid. The water consumption is 22 m^3/tonne and conductivity is 700 μs/cm, so further water savings seem possible.

5 DEMONSTRATED CONTROL TECHNOLOGY

5.1 Discharge Prevention at Source

SUMMARY Many of the pulp and paper manufacturing processes used in Ontario can be modified to reduce effluent discharges at the source. This results in a reduced consumption of energy and raw materials and generation of solid wastes, and always lowers the need for external effluent treatment. Known by various names such as "Pollution Prevention at Source", "In-plant Control" and "Process Modifications", these technologies are particularly well developed for the kraft process which is one of the two principal sources of effluent in the Ontario pulp and paper industry.

All types of mills can reduce water flows to below 50 m^3*/tonne product. This will reduce discharges of many pollutants by a small amount. The prime significance is that the minimum concentrations of BOD, TSS and many other contaminants attainable in the proven effluent treatment processes reach a minimum "floor", so that flows must be minimized if minimum effluent discharges are to be attained. Design and management of the white water system play a major part in controlling effluent flows, and the in-plant modifications mentioned below for specific pulping processes generally result in concurrent flow reductions.*

Technology available for control of effluent parameters other than flow is dependent on the manufacturing process used. For kraft mills the best available technology for reduction of effluent discharges at source would be dry debarking, chip screening by thickness, extended cooking in the digester, high-efficiency pulp washing, oxygen delignification, and substitution of chlorine by chlorine dioxide in bleaching. For the sulphite/mechanical sub-sector the choice is limited to replacement of the sulphite pulping operation by TMP or purchasing kraft pulp to reinforce the groundwood pulp which is the principal pulp furnish.

Technologies for control of effluent discharges at source are being developed at an increasing rate by equipment vendors, research organizations and the mills themselves, so no mill is completely up-to-date in their application. Some of these technologies can be readily retro-fitted. Others are routinely installed in new installations but are extremely expensive to retrofit, except perhaps as part of a major mill rebuild.

5.1.1 Dry debarking

Before the logs are converted to chips, the outer bark and dirt contamination must be removed. The process for carrying out this operation is termed **debarking** and may be a wet or a dry process. The early method of debarking involved removal of bark in drum barkers. Wet and dry drum barkers are commonly used in the industry. Wet drum barkers produce cleaner chips compared to the dry drum barker.

The one possible replacement technology for wet drums is the mechanical ring barker. These are well developed and represent the latest technology. The ring barkers are particular suited to areas that have small diameter logs and are popular in the BC interior mills. The drive to reduce effluent discharges is one of the main reasons why dry debarking systems were developed.

The cambium shear barkers are used for whole log debarking and produce clean logs and a dry bark that is easily burned. This type of barker takes advantage of the weakness in the natural bonding between the bark and the wood.

The separation of bark from wood is an essential part of wood preparation for any pulping process. Thoroughly debarked wood is essential for a clean pulp. Any residual particles are removed during the bleaching process in kraft mills. The removal of bark also avoids wastage of cooking and bleaching chemicals. This in turn reduces the load on the chemical recovery cycle and also minimizes the load on the effluent system.

For quality control purposes, dry debarking machines must be well maintained. This is particularly true for the hard steel tips of the scraping blades that are a key part of the machine. If the debarking units are well maintained, good debarking performance can be accomplished even when frozen logs are debarked under winter conditions.

The environmental benefits of dry debarking are widely accepted. Nevertheless, it is considered by some newsprint manufacturers that dry debarking does not produce wood that is sufficiently clean for paper. However dry debarking is used by many newsprint mills, including Boise Cascade at Kenora and CPFP at Thunder Bay, and most mills with wet debarking systems purchase some of their wood in chip form from sawmills which use dry debarking equipment. In many Canadian bleached kraft mills, dry debarking is used even under severe winter conditions to produce very clean market pulps. The authors consider that it would be technically feasible to replace wet debarking by a dry process in all Ontario mills.

Dry debarking is always more desirable environmentally than wet debarking, and has been almost universally adopted in mills built since the mid 1970s. The alternative technology trains evaluated in Section 7 assume that there would be no change in debarking practices in the mills concerned due to the difficulty of estimating the capital costs of the necessary modifications. Effectively, many mills are moving steadily towards dry debarking, since they are generally increasing the proportion of wood that is being purchased in the form of (dry debarked) chips from sawmills.

5.1.2 Chip processing

SUMMARY The benefits of upgrading the chip preparation system are directly related to the performance of the original system. When a poor chip processing system is replaced by an upgraded modern system, annual savings of $1,000,000 to $3,000,000 for a 1000 ADt per day mill can be realized.

It is well known to pulp mill operators that the quality and uniformity of the chips fed to the digester have a significant impact on effluent quality. Uniformity of pulp is a prerequisite for effective use of oxygen delignification, high chlorine dioxide substitution and the precise control of the bleach plant that is essential for reduction of emissions of chlorinated compounds and other pollutants at source. High chip quality also reduces the risk of accidental losses to sewer caused by process upsets. The authors were unable to quantify effluent quality improvements resulting from upgrading chip processing systems so as to include them in the alternative technology trains. However, as discussed below, it is apparent that it is quite reasonable to justify upgrading poor chip processing systems on economic grounds, so it is generally assumed that this has been undertaken, or will be prior to installation of process modifications to reduce effluent discharges at source in kraft mills.

By screening chips according to thickness, rather then by length, and reprocessing the thicker chips, knotter rejects can be reduced to at least half. The rejects then will be more truly knots and compression wood. Precursors for TCDD/TCDF are concentrated in compression wood if present in the tree and can be rejected from the system. There will also be a reduction in the brown stock screen rejects which will significantly reduce the load to the waste disposal system.

The improved chip dimensions will promote more uniform cooking and reduce cooking chemical consumption. The more uniform cooking means less variation in bleach plant feed leading to better control and less tendency to over bleach. These improvements have a favorable impact on the effluent quality leaving the pulping line.

There is a need for caution in generalizing since there are many different processes currently in use. The industry trend is towards manufacturing and screening of chips according to thickness rather than chip length, as was the normal practice in the past. Although liquor penetration into the chips is faster along the grain, the distance across the thickness dimension of a chip is much less. Liquid penetration of the chip is normally controlled by the slower penetration across the thickness rather than the length. This is especially true for the kraft pulping process and is generally true for most chemical pulping processes. Some pulping processes use chemicals that travel much more rapidly along the grain than across the grain. In some of these cases, the rate of penetration across the grain is so slow that the grain length is the controlling factor.

There are several different approaches to producing pulp wood chips, and the method selected is normally related to the major products of the operation. Disc chippers are utilized for sizes ranging from small pieces of log trim up to whole, large diameter logs. Other chip producing equipment is designed to shape lumber as it chips off the excess wood from the logs or from rough lumber slabs cut from logs.

The modern disc chipper was first patented about 100 years ago. The basic principles remain the same today, although improvements have been made to increase productivity and to control chip length requirements. With the attention shifting more and more towards chip thickness, the chip producing equipment is currently being set up to favour the thickness desired more so than some specified length. This can mean different settings for chips produced in the winter, when frozen wood tends to shatter more, than during more favourable weather conditions. There are many variations in disc chipper design, including different methods of exposing the logs to the chipping disc, securing the logs, and controlling the chip size. About 75% of the world supply of pulp wood chips are produced with disc chippers.

The quality of the chips produced by disc chippers depends greatly on the type of material being converted. Whole logs produce uniformly sized chips, while randomly sized pieces of wood can produce wide variations in chip shape and size. It is extremely important to have chippers that are designed for the raw material on which they will be used. By careful design and good maintenance of the disc chippers, a product well suited to the pulping process being served can be obtained.

Changes in sawmill technology took place early in the 1960s to reduce raw material waste and to reduce manpower requirements. In the major lumber producing regions, changes were extensive. Today, approximately one-third of the supply of pulp wood chips in North America is made from sawmill residuals. In a modern sawmill, where fibre recovery is efficient, lumber cutting devices are especially designed to produce both lumber and chips suitable for sale to pulp mills. A minimum amount of waste in the form of sawdust and other debris, is produced by a well-designed system.

In a modern well operated pulp mill, not only are the oversize and the undersize materials removed but also selective screening takes place to enhance desirable size distribution. The screening operation has become a corrective step rather than a protective step. Therefore, it is not unusual for an elaborate chip screening system to be installed for both continuous and batch digesters.

The latest technology chip screens are designed to screen out over-thick chips and remove sawdust. The over-thick chips are passed to a corrective operation in which the chips are sliced with the grain thereby producing chips of uniform thickness. The end result is that the liquor penetration is well controlled, pulping is more uniform, and knotter and pulp screen rejects are minimized. The more uniform pulping within the digester leads to a more uniform and stronger pulp.

Chip screening systems to carry out the controlled separation of undesirable material are usually made up of a combination of disc and slotted chip screens. The oversize chips in a kraft operation are removed by scalping screens set to reject material with a thickness greater than 8 mm. This material is then passed to a slicer and the reprocessed material is returned to the chip screens. Primary screens follow the scalping screens and the trend is towards secondary screens. Within these screening machines there are usually both slots and perforations with the sizes chosen on the basis of local needs.

In the colder climates, the winter screening of chips was frequently difficult. The frost and snow that followed the chip flow would tend to melt during the screening operation and to refreeze as it left the screen. The refreezing then led to the bottom screen mesh blinding over and no effective screening would take place. This caused a great deal of difficulty in the operation of continuous digesters. Chip screen and digester manufacturers responded by design changes to their equipment. The digesters were made less sensitive to sawdust and pin chips while screens were designed to avoid blinding. One such screen system involves flexible screen panels that are self cleaning so that blinding under any conditions is avoided.

With this latest technology in chip screening, a uniform digester feed is assured. This brings about more uniform liquor penetration that assures a higher quality and more uniform pulp. The pulp product is easily bleached and the tendency to over-bleach to remove shives and coloured fibre is significantly reduced. The better controlled bleach operation produces lesser amounts of chlorinated organics. Knotter and pulp screen rejects are reduced in volume leading to greater efficiency of raw material use as well as avoiding a solid waste burden.

An example of a major improvement in mill operations resulting from modernized chip processing was reported by McIntyre (1991) who described the impact of the new woodroom for the Weyerhaeuser mill at Prince Albert, Saskatchewan. The project cost approximately $22,000,000 and apparently involved building an entire wood handling system to allow for the increased use of aspen for the new fine paper machine. The results of the project provide an opportunity to assess the benefits of improved chips at one kraft operation. The benefits reported by McIntyre (1991) included a 3.75% reduction in load to the recovery boiler which was translated into a 35 ADt per day production increase. The reduction in loading is directly related to reduced knotter and pulp screen rejects, reduced chemical requirements and losses, improved digester operation and other items. The total benefits translate into a predicted savings of $ 5,300,000 annually.

The portion of the cost for upgrading the chip screening system was $9,900,000, but most of the reported savings in pulping would be traceable to the chip screen system. This is reported in the reference and is in keeping with the author's experience. The savings realized by eliminating the pneumatic transfer of chips would be significant but not a major part of the $5,300,000 annual savings predicted.

5.1.3 Continuous digester

Until about 1950 kraft pulp was invariably produced in batch digesters, but continuous digesters were developed by several companies, with the first Canadian installation in Hinton, Alberta in 1955.

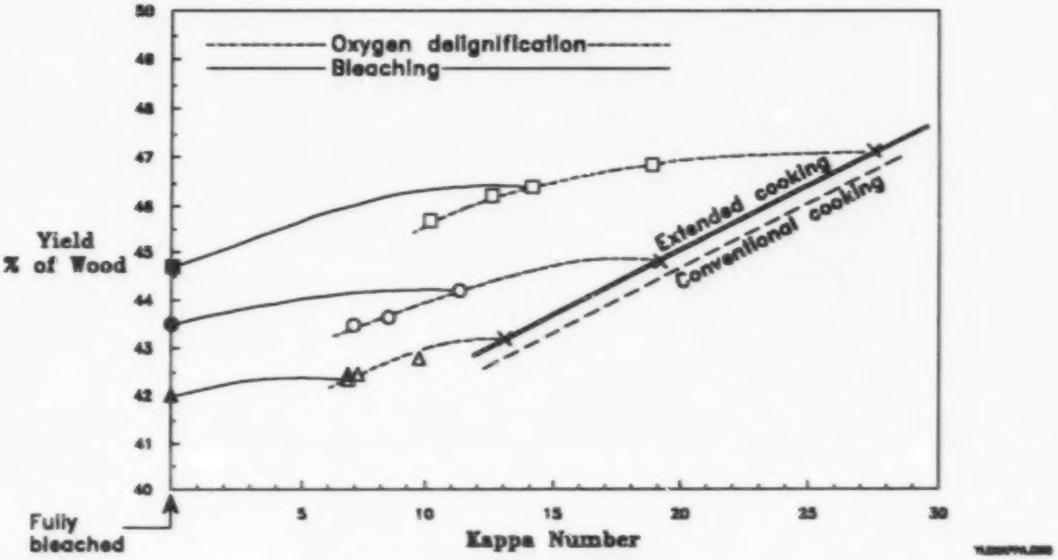
To assure that strength and yields are reasonable, close control over the cooking cycle must be maintained. Improved strengths and yield have been achieved by technological changes in control methods. These efforts eventually led to the development of continuous cooking processes that were targeted at reducing the chemical reaction shocks and providing less drastic cooking conditions. One such process was developed by Kamyr and who are now in a world dominating position in the kraft industry. Eventually the process evolved to produce higher yields and stronger pulps.

The advantages of the continuous digester are similar to any continuous process over a batch operation. These are steady-state conditions that produce a product at a continuous rate, and use raw materials, steam, power, and manpower at consistent and relatively easily predictable rates. It is generally easier to operate continuous digesters with less accidental spilling of pollutants, than for batch processes. The product strength is generally considered to be superior to the old batch methods. Some new batch cooking techniques also provide equally improved pulp qualities.

The disadvantage, over batch, is that the continuous digesters are less flexible than batch, particularly where several pulp grades are involved. The batch system allows for more than one pulp grade to be produced at one time by using different digesters for different pulp grades or wood species. A continuous system normally performs better with uniform raw materials and also requires sophisticated operating controls. Almost all new kraft mills built since 1970 use continuous cooking processes, and most engineers in the industry would agree that they are more desirable environmentally than batch digesters. It is usually technically feasible to replace a batch digester system with a continuous one, but the capital cost is high (typically about $50 to $100 million).

5.1.4 Modified cooking

The high concentration of active chemicals present at the beginning of conventional pulping gradually falls off as the cooking process proceeds. The wide swing in chemical concentration leads to very drastic action at the beginning of a cook and very gentle pulping at the end. In the early 1980s Hartler developed the concept of "modified" cooking. The objective was to level off the alkali concentration throughout the cook so that the initial action would be less aggressive, and additional lignin could be removed in the latter stages of the process. Effectively, this was the "extended cooking" concept.



Source: Gullichsen 1991

Figure 31 Yield vs Kappa for extended delignification and bleaching softwood kraft

Through the late 1980s, vendors of both batch and continuous digester systems developed practical, commercial kraft pulp cooking systems based on Hartler's modified cooking concept.

In the Modified Continuous Cooking (MCC) process the cooking liquor is added at several points, instead of only at the top of the digester as is indicated in the conventional continuous digester shown in Figure 32 on page 168. By avoiding the high concentrations of chemical at the beginning of the cook, there is less damage to the fibres. By leveling out the active chemical concentration over time, more lignin can be dissolved than in traditional cooking. This combination of less damage to the fibre and greater lignin removal leads to stronger pulp even at lower Kappa number (lower lignin) while maintaining normal or better yields.

A vital part of the MCC process is the increase in time for liquor penetration. This is achieved by having a penetration vessel that allows a longer time for liquor penetration to take place after the air within the chips has been displaced. Penetration is aided by hydraulic loading of the vessel before the temperature is raised to the cooking level. As the active chemicals are consumed by the raw wood, they are replaced by the addition of fresh chemicals at strategic points in the digester.

Current technology will allow pulps to be produced at Kappa numbers of under 10 for hardwood and Kappa numbers under 15 for softwood. This corresponds to lignin contents of about 1.5% and 2.3% respectively. Full scale mill experience has demonstrated that these low Kappa pulps have strengths equal to those of the 25 to 35 Kappa pulps produced by conventional cooking methods (Elliott 1989, Whitley 1990). The Longview Fibre mill pulped to very low Kappa with only modest loss in strength (Haas 1990). The pulp viscosity was low, but under extended cooking conditions the viscosity is no longer a valid indicator of pulp strength.

These experiences suggest that extended delignification within the digester has not yet been exploited to its maximum potential, and that further developments can be expected over the next few years. The limiting factor could well be yield loss. If the operating techniques or equipment modifications can be developed so that post-bleaching yield is acceptable, or the loss minor, then it appears that very low lignin content pulps will be produced in future by extended cooking technologies.

Pulping yields

Extended cooking can produce pulp at equal or slightly better overall yield (wood chips:finished bleached pulp) than conventional cooking if the Kappa number is lowered moderately. There is some loss of yield if the cook is extended to the lowest Kappa number possible without degrading pulp strength. Effluent quality will always be improved by extending the cook as far as possible, since it will increase the proportion of the substances removed from the wood in the pulping/bleaching process that is incinerated in the recovery boiler. There will be an additional benefit in the reduction of discharges of organochlorines since the need for chlorinated bleaching chemicals in subsequent bleaching stages will be reduced. The calculations and comments in this report generally assume that the extended cooking process would be designed and operated to improve effluent characteristics to the greatest extent that is technically feasible. **This will result in some loss of overall pulping yield** and appropriate cost allowances are included in the report. Figure 31, which is based on laboratory processing, indicates that if softwood kraft is cooked to 15 Kappa, and bleached with oxygen and then with traditional bleaching chemicals there would be a 2% loss in overall pulping/bleaching yield. Many mill technical staff with experience in operating extended cooking systems have commented that the loss in the brown stock screens drops dramatically. Most mills lose between 1% and 3% of unbleached pulp in screening. A mill equipped with effective chip preparation equipment as discussed on page 157 would be at the lower end of this range. The authors have therefore assumed in calculating operating costs that the actual loss of fibre caused by implementation of extended cooking technology would be 1%. It is impossible, to determine a yield loss of this magnitude accurately in a mill, but it cannot be ignored in evaluating process economics.

Limits of extended cooking

As indicated above, it is technically feasible to cook softwoods to 15 Kappa and hardwoods to 10 Kappa. In view of the loss of yield, the only justification for a mill choosing to operate in these conditions would be to improve effluent quality. The alternative technology trains K4 and K5, discussed in Chapter 7, are intended to attain the best possible effluent characteristics, so are based on these low Kappa numbers. If broader issues, such as the advantage of conserving forest resources and costs are considered, the optimum target Kappa number would probably be somewhat higher.

Retrofitting modified continuous cooking

Existing installations of some conventional digesters may be retrofitted to use the Modified Continuous Cooking technology. Technical feasibility depends upon several factors including space availability, age of the installation, capacity limitations of the existing equipment, and other site specific requirements.

Where the existing installation is old and/or overloaded, it is usually technically feasible to convert the existing digester into the penetration vessel, and install a new digester for cooking. This is a major capital cost[56], normally less expensive than a completely new system, but providing all the benefits of the current technical developments. It is not feasible to retrofit all existing continuous digester systems.

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[56] *Refer to Chapter 8 for estimated costs for Ontario mills.*

In some cases a relatively new digester that is operating at or below design capacity can be modified to take advantage of MCC mode to some extent by installing cooking liquor addition points to the washing section and other appropriate points. Performance will approach that of a new MCC system, and local conditions will dictate how close it will be. This approach is relatively low cost and easily carried out.

The authors consider that the MCC process is demonstrated technology and technically feasible in Ontario. Most mills would have to install new digesters to realize all the potential environmental benefits of MCC technology. However, if the Hot Alkali Extraction procedure discussed on page 228 is developed to a proven industrial process, then many of the benefits of extended cooking will be available at relatively low cost.

Modified batch cooking

For batch digesters, implementation of extended cooking technology involves maintaining liquor concentrations at a more uniform level throughout the cooking cycle. Initially the intent was to improve the batch energy consumption performance to make it more competitive with the continuous process. Patents were granted to Fagerlund and the success of the Modified Batch Cooking (MBC) process was reported by several groups as summarized by Andrews (1989).

The changes brought about by the MBC process led to improved pulping efficiency and pulp strengths, so that the MBC process can produce pulps comparable to those manufactured by the MCC process. There are at least two systems commercially available from well-established vendors:

The Rapid Displacement Heating (RDH) System marketed by Beloit Inc.
The Super Batch System marketed by Sunds Defibrator, Inc.

Extended cooking to Kappa number levels of 15 to 18 for softwood and 8 to 10 for hardwoods using the RDH process were described in the Andrews (1989) summary. Somewhat similar results were reported by Pursiainen (1990) using the Super Batch process in two Scandinavian pulp mills.

The MBC process involves impregnating the chips with warm black liquor under pressure to improve air removal and improve liquor penetration, leading to more uniform cooking conditions. The warm black liquor is displaced with hot black liquor and white liquor and the chip charge is then cooked. After cooking the hot (spent) black liquor is displaced with wash liquor from the first brown stock washer, and stored to provide the hot black liquor for a subsequent cook. The process was developed to reduce steam requirements, and is technically quite effective in doing so. The equipment is much more complex that for conventional batch digesters, and includes several pressure vessels at least as large as a digester and extensive piping, valves and control systems. The complexity increases as the number of digesters increases. While the basic cycle described by several of the above mentioned authors is simple in concept for a single digester, it requires careful scheduling to operate several digesters simultaneously, even in theory. In practice, the inevitable upsets caused by equipment failure and operator error can lead to major losses in production to attain the desired schedule.

Retrofitting modified batch cooking

In a standard batch digester system, the operation of the digesters is synchronized to allow consistent consumption of cooking liquor, steam, electrical energy, storage capacity, drying capacity, and manpower. The greater the number of digesters and the more pulp grades that are produced, then the greater the importance of operating coordination.

The use of batch digesters provides a high degree of flexibility for a production plant. Under these conditions each individual digester may be programmed separately. This allows cooking different wood species in different digesters according to customer requirements. It also allows for shutting down of individual digesters for maintenance, or for operating adjustments.

The shutdown of a solitary digester does not jeopardize the production schedule of other digesters when they are operated under standard cooking conditions. It is a simple case of missing a blow to the blow tank and then joining the cooking sequence at a later opportunity.

The MBC technology can be retrofitted to an existing cooking system. However, it is not feasible for all existing batch digester systems to be converted to the modified system. Mill lay out and operating conditions should be conducive to the modifications, otherwise it appears that the changes could make the operation very complicated.

The flexibility of the conventional system will have to give way to more restrictive practices. This would take operator adjustments as well as equipment modifications. It would appear that the success of retrofitting would be related to the existing number of digesters. It may be beneficial to have two or more independent systems if a large number of digesters are involved. One mill, where an RDH system was retrofitted, subsequently modified the installation along these lines, and at the time of writing are satisfied that the system will meet their requirements.

The authors have contacted industry staff responsible for operating batch digesters which have been modified for extended cooking, and are advised that the pulp quality has been very good, and energy savings have met expectations. On the other hand, there are reports of difficulties in operating the retrofitted systems at rated production levels. This suggests that more development work is required and this appears to be taking place.

The authors reviewed the existing installations of extended batch cooking at rated production levels at Val d'Osta, and Bennetsville. They consider that the process control problems have not yet been solved. There are no obvious imminent solutions to these problems, so it is not considered that retrofitting extended cooking to batch digester systems represents demonstrated technology for the Ontario kraft mills at the time of writing. The only proven way of implementing the extended cooking concept in Ontario mills which use batch digesters would be to replace them with a continuous digester.

5.1.5 High efficiency pulp washing

After the cooking chemicals have been exhausted, the next unit process is the first step in the chemical recovery cycle. This process, the brown stock washers, separates spent chemicals and dissolved wood components from the fibre released by the cooking process. The separation is carried out in stages in a manner that minimizes the amount of water required to efficiently remove the dissolved materials.

The initial stage may occur in the digester, but the main washing stages are a separate process. In recent years the washers have been recognized as having a major impact on the mill effluent characteristics.

If the washing is inefficient then chemicals and dissolved wood remain with the pulp and some is later drained into the wastewater system when the pulp is thickened. The spent chemicals and the dissolved wood contribute to the COD and BOD load discharged to the effluent system. A second impact occurs when poorly washed stock is passed on to the bleach plant. If chlorine-based bleaching chemicals are used, then the dissolved wood materials contribute to the chlorinated organics (AOX) that are formed in the bleach plant.

Due partly to environmental concerns, increased attention has been given to the brown stock washing area. As a result a number of newly designed washing devices have been put on the market. These can be described as high efficiency washers. There are several types including pressure displacement washers, belt washers, pressure filters, presses of various types as well as upgraded drumwashers.

The various types of washing equipment all have the ability to provide well washed stock. It is a matter of local preference and how the equipment fits existing systems. Four and five stage washing is fairly common. A washer system performing well should be able to provide a stock that has less than 10 kg/ADt of total soda. A visit to a mill using a belt washer on sawdust revealed that the soda loss was 6 to 8 kg/ADt.

5.1.6 Pre-chlorination E_O

The addition of oxygen to the first extraction stage is common for bleached kraft mills. The key to allowing the addition of oxygen at this point is availability of efficient mixers. It is a low cost change that has a positive impact on costs, capacity, and effluent quality. A variation of this application is positioning an extraction stage in front of the chlorination stage.

The installation of a pre-retention tube along with an efficient mixer ahead of the chlorination stage allows an operation to provide a low level oxygen delignification step. The reduction in chlorine consumption remains the main advantage. However, in this position it also permits the mill to use a second control point for the bleach plant incoming Kappa number so that the bleach plant operates more uniformly. Steady operation is an important factor in environmental performance as well as maintaining pulp quality.

The pre-chlorination E_O treatment has the advantages of low capital costs relative to the conventional oxygen delignification processes discussed below, and a significant reduction in AOX. The demand for equivalent chlorine is reduced, so the mill can continue to use the same amount of chlorine dioxide in the chlorination stage, effectively increasing the degree of substitution without requiring additional chlorine dioxide generating capacity. Pre-chlorination Eo is often described as the "poor man's oxygen delignification system", which is apt. In general, it provides similar environmental features to those of oxygen delignification, but to a lesser degree.

The disadvantages appear to include higher operating costs and less effective reduction in AOX than would be attainable with a conventional oxygen delignification system. Some mills have considered installing a pre-chlorination E_O stage without recovering the washer filtrate. This will be effective in reducing AOX discharges, but not BOD, colour or other pollutants associated with the black liquor.

Pre-chlorination E_O is a quick, perhaps short term, solution which is not used in the technology trains in this report but may be appropriate in some situations.

5.1.7 Oxygen delignification

SUMMARY Since the early 1970s, oxygen delignification has been installed in many European mills, as well as a growing number of mills in the US and in Canada. The filtrate from an oxygen delignification stage may be recycled to the chemical recovery system. The installation of an oxygen stage will allow most bleached kraft mills to reduce bleach plant BOD discharges by approximately 50% and colour by 60%. Discharges of organochlorines will be reduced by approximately 35% to 50% and a 50% reduction of TER. Oxygen delignification reduces the Kappa number by approximately 50%.

The terms **"oxygen delignification"** and **"oxygen bleaching"** are often used interchangeably to refer to the process discussed in this section. The term "Oxygen Bleaching" is also sometimes used to refer to the addition of elemental oxygen to the caustic extraction stage, described on page 78.

The raw effluent from systems using oxygen is generally highly coloured and has somewhat higher BOD than chlorination bleaching effluent, so the maximum environmental benefits are realized only if the filtrate from the oxygen stage is recycled to the chemical recovery system, which is the universal practice. However, the efficacy of oxygen delignification in reducing the discharge of chlorinated organic materials is not dependent on such a recycle. The installation of oxygen delignification will allow most bleached kraft mills to reduce bleach plant BOD discharges by approximately 50% and colour by 60%. Discharges of organochlorines will be reduced by approximately 35% to 50% (Norström 1987).

There is some information on reduction of acute toxicity with oxygen delignification. An overall 50% reduction in amount of toxicity (i.e. Toxic Units per tonne of pulp) has been claimed by Arhippainen (1987), and reductions of 50% to 70% in acute toxicity to fish are listed by Idner (1987). There was a definite reduction of toxicity in Microtox tests, in which the toxic concentration was raised from 4%, for bleach plant effluents without O_2 to 33% with O_2 pretreatment (Germgård 1985). In the same research project, mutagenicity of chlorination effluent was reduced from a response level of 600 to levels of 20 to 40 with O_2 delignification. Some comparisons do not show such great advantages, for example effluents collected from mills with and without oxygen delignification did not yield clear differences in toxicity (IPK 1982). The laboratory tests of

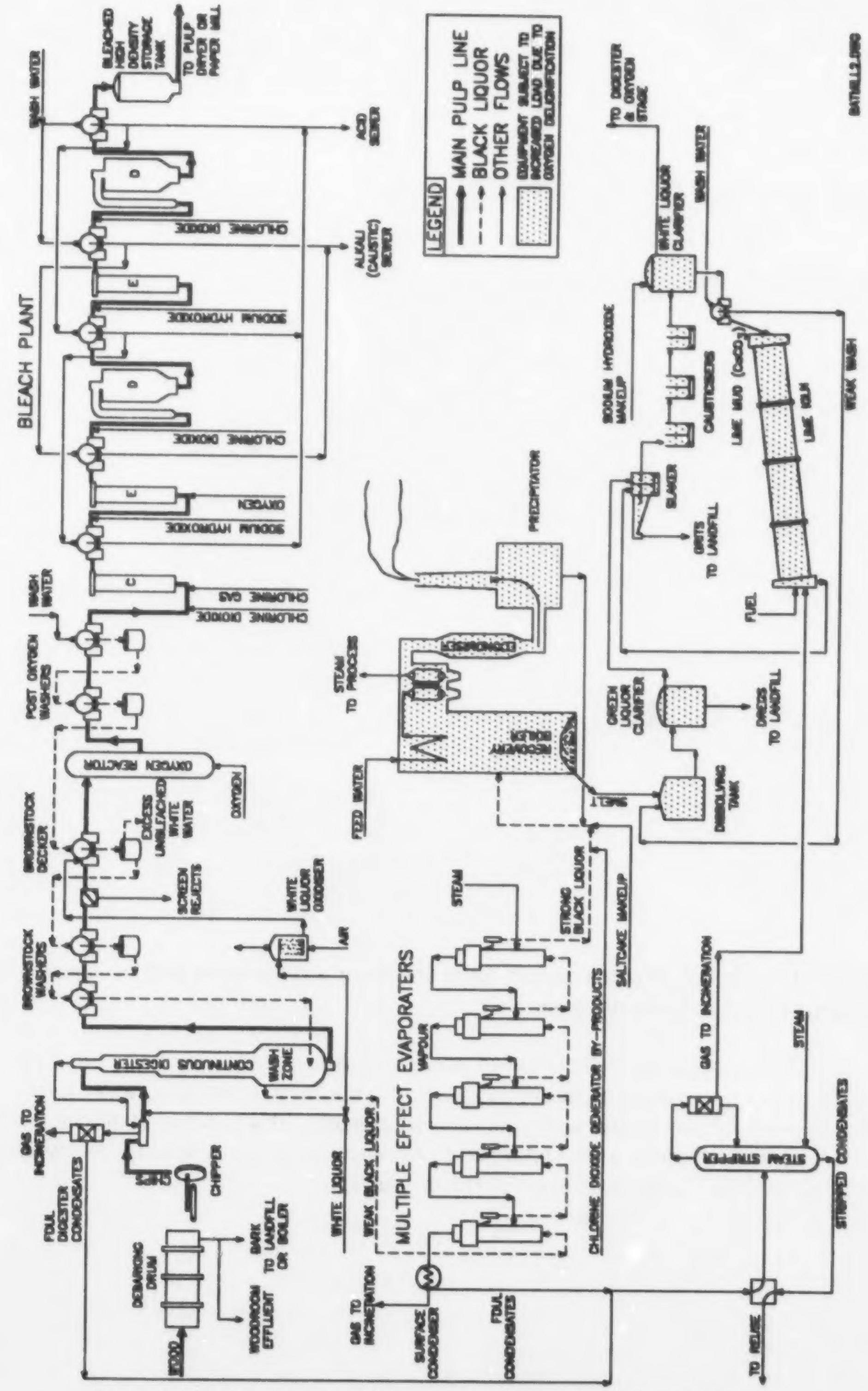
BLEACH PLANT
LEGEND
MAIN PULP LINE
BLACK LIQUOR
OTHER FLOWS
EQUIPMENT SUBJECT TO INCREASED LOAD DUE TO OXYGEN DELIGNIFICATION
WASH WATER
BLEACHED HIGH DENSITY STORAGE TANK
TO PULP DRYER OR PAPER MILL
ACID SEWER
ALKALI (CAUSTIC) SEWER
CHLORINE DIOXIDE
SODIUM HYDROXIDE
OXYGEN
CHLORINE GAS
C
E
D
POST OXYGEN WASHERS
OXYGEN REACTOR
OXYGEN
BROWNSTOCK DECKER
EXCESS UNBLEACHED WHITE WATER
SCREEN REJECTS
BROWNSTOCK WASHERS
WHITE LIQUOR OXIDIZER
AIR
CONTINUOUS DIGESTER
WASH ZONE
GAS TO INCINERATION
CHIPS
CHIPPER
FOUL DIGESTER CONDENSATES
DEBARKING DRUM
BARK TO LANDFILL OR BOILER
WOODROOM EFFLUENT
WOOD
WHITE LIQUOR
WEAK BLACK LIQUOR
MULTIPLE EFFECT EVAPORATERS
VAPOUR
STEAM
STRONG BLACK LIQUOR
SALTCAKE MAKEUP
CHLORINE DIOXIDE GENERATOR BY-PRODUCTS
FEED WATER
STEAM TO PROCESS
ECONOMISER
RECOVERY BOILER
PRECIPITATOR
SMELT
DISSOLVING TANK
GREEN LIQUOR CLARIFIER
DREGS TO LANDFILL
SLAKER
GRITS TO LANDFILL
FUEL
LIME KILN
LIME MUD (CaCO3)
CAUSTICIZERS
SODIUM HYDROXIDE MAKEUP
WHITE LIQUOR CLARIFIER
WASH WATER
TO DIGESTER & OXYGEN STAGE
WEAK WASH
GAS TO INCINERATION
STEAM
STEAM STRIPPER
STRIPPED CONDENSATES
TO REUSE
SURFACE CONDENSER
GAS TO INCINERATION
FOUL CONDENSATES
BATMILL2.DRG

Figure 32 Typical kraft mill flowsheet with oxygen delignification

Most mills which have installed oxygen delignification systems have also taken steps to ensure that the preceding screening operations operate on a closed cycle (a "closed screenroom"). While this is desirable for the reduction of BOD and colour, it increases the load on the mill's recovery boiler. Where it is desired to use oxygen delignification to reduce the discharge of chlorinated organic compounds, it is technically feasible to operate with an open screen room to reduce the amount of organic material returned to the recovery boiler.

The economics of oxygen delignification are dependent on local prices for oxygen relative to molecular chlorine and the chemicals for on-site manufacture of chlorine dioxide. The published data indicate that the operating costs for bleached kraft mills incorporating oxygen delignification stages are lower than for the traditional chlorine based systems. The authors have calculated that the average Ontario softwood kraft mill can save in the order of $8/tonne pulp in direct operating costs by installing oxygen delignification systems, based on Ontario chemical prices prevailing in early 1991[57]. The savings will vary according to local conditions, and depend mostly on the ability of the existing bleach plant to produce satisfactory quality pulp. The chemical savings were calculated individually when estimating costs as discussed on page 259 of this report.

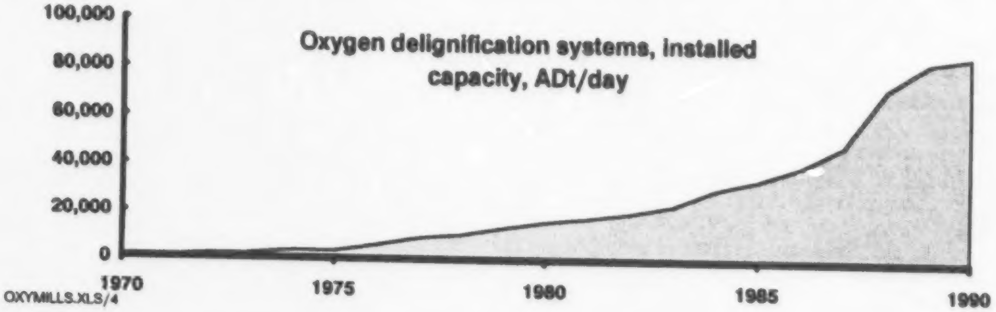

Figure 33 Oxygen delignification systems installed and under construction (worldwide)

Oxygen delignification is being used to produce a variety of pulp grades, and there are about 120 oxygen delignification systems operating in kraft mills around the world, with at least another dozen under construction. When oxygen delignification was introduced in the early 1970s, the regulations pertaining to new mill construction in most parts of the US and in Canada were such that a biological treatment system was necessary to comply with the BOD and/or toxicity criteria. The environmental advantage of using the oxygen process was limited to a modest marginal reduction in effluent treatment costs. However, many Scandinavian mills were permitted to operate without biological treatment systems, provided that they installed oxygen delignification stages; so it was more economically attractive for them to do so than for North American mills.

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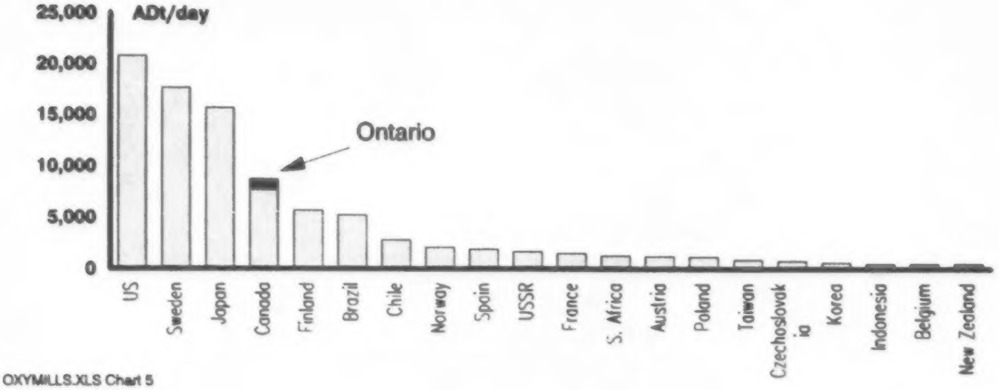
[57] *The calculation includes chemicals, energy and assumes that the mill has adequate recovery boiler capacity to burn the additional black liquor load without reducing production.*



OXYMILLS.XLS Chart 5

Figure 34 Geographic distribution of oxygen delignification systems

Oxygen delignification is demonstrated technology that has been widely accepted, but is less commonly used in Canada than in most major pulp producing regions. The E.B. Eddy mill at Espanola has had two oxygen delignification systems since before 1980, but remained the only one in Canada until 1990. There are currently three other systems running in Western Canada, and Malette has proposed installation of an oxygen delignification system at the Smooth Rock Falls, Ontario, mill. Oxygen delignification systems are under construction at the Cariboo Pulp and Paper Co. mill in Quesnel, BC, and at Alberta Pacific mill at Athabasca, Alberta. The geographic distribution of oxygen delignification systems is shown in Table 20, along with an indication to the extent of the use of the process in each area.

Table 20 Geographic distribution of oxygen delignification in North America

Location	Bleached kraft capacity, air dry tonnes/day Oxygen delignification	Total capacity	Fraction Oxy delig
Alberta	3,400	4,300	79%
BC	2,100	14,000	15%
Ontario	950	6,300	15%
Total Canada	6,500	31,000	21%
Total US	18,500	68,500	27%

There are no oxygen delignification installations in provinces omitted above. Production data are from various sources including Lockwood-Post's directory, oxygen delignification system vendors and personal contact, and may not be completely consistent, but do indicate relative status of installations.

There are no published surveys of the reasons behind the installation of oxygen delignification systems. Personal contact with several industry personnel closely involved in decisions both for and against oxygen delignification indicate that environmental pressures, mostly from regulatory authorities but also public opinion and customer interest, have been the major factor leading to installations. The authors are unaware of any regulations requiring the installation of this process, but personnel in several regulatory authorities have indicated verbally that no expansions or new bleached kraft mills would be authorized without incorporation of oxygen delignification. When examining the extent of adoption of the oxygen delignification process by various companies, it is apparent that there are clear corporate preferences, with some major bleached kraft pulp producers (Champion International and Union Camp) using the process for virtually all their bleached pulp, and others not at all. The installations include greenfield mills, major rebuilds and straightforward retrofits in roughly equal proportions.

Concerns have been expressed by many pulp producing companies about the risks of oxygen delignification degrading pulp quality, particularly with respect to strength. Although there are substantiated claims that strengths have been maintained when oxygen delignification has been used, the concerns remain and some companies have an unwritten but strongly followed policy of avoiding the process. The concerns are valid where the mill depends on excellent strength properties to retain its customers. Some mills have elected to install two stage oxygen delignification in the expectation that this would minimize any strength loss.

There are two principal oxygen delignification processes, as discussed below.

High consistency oxygen delignification

In high consistency oxygen delignification systems the washed, unbleached pulp is dewatered to 25% to 30% consistency in a press and fed to a pressurized reactor where gaseous oxygen is introduced. Sodium hydroxide is added to the pulp to control the pH to about 10, and about 1.4 kg magnesium salt ("viscosity protector") per tonne pulp is also added to control the tendency of oxygen to attack the cellulose fibres. The reactor is a pressure vessel with an internal fluffer and/or agitator to disperse the high consistency pulp to ensure even contact with oxygen. The gaseous oxygen is fed to the reactor directly, and a small bleed to atmosphere is maintained to purge air and small quantities of carbon monoxide. After discharge from the reactor, the pulp is washed, either on a drum washer or a diffusion washer, in a similar manner to that used for the unbleached stock from the digester. The filtrate from this washing stage contains about half of the BOD, toxic material and coloured material which would be discharged from a conventional chlorine based bleach plant. A typical high consistency oxygen delignification system is shown in Figure 35. The only oxygen delignification system operating in Ontario, at Espanola, uses the high consistency process.

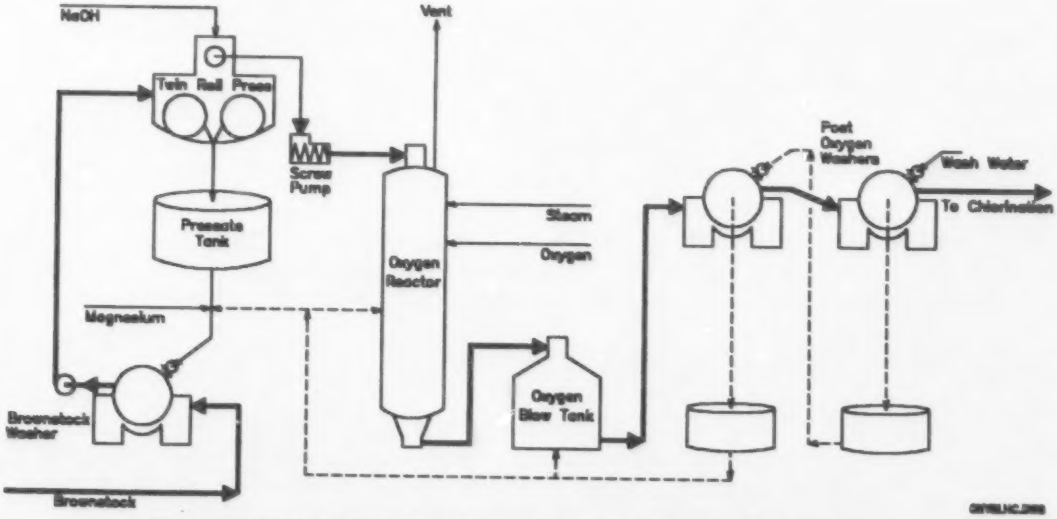


Figure 35 Typical high consistency oxygen delignification system

Medium consistency oxygen delignification

Since the first commercial scale high consistency oxygen delignification systems were commissioned in the early 1970s, there has been considerable evolutionary development, as is characteristic of any new technology. Most of this has had little effect on the environmental aspects of the process, but the demonstration of the feasibility of operating the process at medium consistency, 10% to 15%, is important in that it allows the construction of oxygen delignification systems at lower capital costs than for the high consistency systems. This process variation is described by Markham and Magnotta (1981) and at the time of writing the suppliers of almost all of the operating high consistency oxygen bleaching systems recommend the medium consistency approach for most applications. The medium consistency process may now be considered as the most popular way of delignifying pulp with oxygen. There have been some recent announcements of new high consistency installations, and engineers involved consider that the high consistency process provides superior delignification. Future installations seem likely to use both variations of the process.

The process flowsheet is presented in Figure 36. The lines containing residual organic substances removed from the pulp are shown dashed. The essential equipment difference is that the pulp can be dewatered to a suitable consistency by a conventional brown stock decker, which already exists in many mills, instead of using a press. It is claimed that at the consistencies used, the pulp is less liable to be degraded by locally high oxygen application, and the potential risk of fire in the reactor is eliminated. The cost of magnesium salt for viscosity protection is claimed to be reduced.

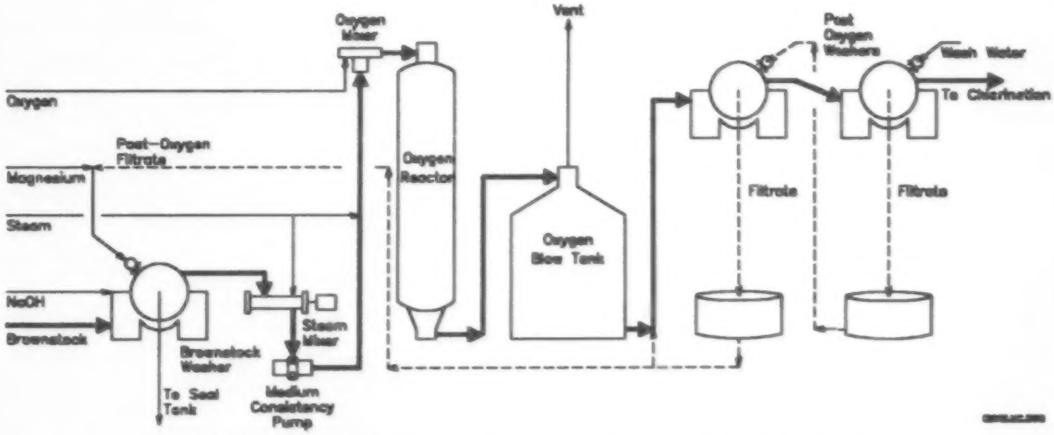


Figure 36 Typical medium consistency oxygen delignification system

Washing following oxygen delignification

If the potential of the oxygen delignification stage to reduce the quantity of chlorinated organic materials in the effluent is to be realized, it is essential to minimize the quantity of organics which pass forward to the subsequent bleaching stages with the pulp. There has been a recent trend toward installing two washing stages after the oxygen stage, which is environmentally desirable, but incurs capital and operating costs. There are at least two mills operating with three stages of washing after the oxygen delignification stage (Tench 1987).

There are many references in the literature to the need for "good" washing following oxygen delignification, but few data. Stromberg (1990) described a useful model for design and prediction of the performance of washing systems. He stated that each kilogram COD carried forward with the pulp to the bleaching stages would require 0.4 to 0.8 kg equivalent chlorine. Poor washing systems can typically allow up to about 150 kg COD to carry forward. Using Stromberg's estimate of equivalent chlorine demand, and the AOX prediction procedure discussed on page 129 one can estimate that this would add in the order of 6 kg AOX to the effluent discharge. In the authors' experience, such poor washing is rare to-day, but was not uncommon in the past. All of the Ontario kraft mills report saltcake losses under 30 kg/tonne pulp, and most report under 10 kg/tonne, indicating moderately good to excellent washing. It is technically feasible to limit the quantity of organics carried forward to the subsequent bleaching process to under 10 kg COD per tonne pulp, and this is a common design basis for new installations. The known saltcake losses from Ontario mill washing systems indicate that COD carried forward probably ranges from about 10 to 40 kg/tonne pulp. The alternative technology trains discussed on page 243 include improved brown stock washing equipment where existing losses are high.

Figure 32 shows a kraft mill, but with an oxygen delignification system installed. Conventional practice would be to install two post oxygen washers, and recirculate the filtrate as shown. However, if the filtrate from the second post oxygen washer is sewered directly, and fresh water used as shower water on the first washer, then the flow of organics into the first bleaching stage would be reduced by about half, at the cost of some increase in mill effluent BOD, and reduction in bleach chemical cost. This is not practiced in any mill known to the authors, at present, but is under study, and serves to illustrate one of the classic chemical engineering trade-offs that have not yet been optimized in current systems. Further improvements will no doubt emerge as engineering experience is gained in minimizing organochlorine discharges.

5.1.8 Bleaching following oxygen delignification

The most commonly used sequence is OC_dEDED, where about half of the total delignification is accomplished in the oxygen stage, resulting in 50% of the BOD and at least 60% of the colour and toxic material in the effluent being recycled to the recovery furnace. Where the C_d stage utilizes chlorine dioxide substitution over about 20%, the effluent colour and toxicity are reported to be further decreased. Recent trends have been towards high substitution, with 100% substitution being practiced in many mills, at least on selected pulping grades.

Other simplified sequences have been proposed, such as OD_cE_oD where the E-stage uses alkali/oxygen extraction as mentioned previously. Such "short" sequences generally have lower capital costs and lower effluent flows than the conventional sequences. They are being used increasingly in new and re-built bleach plants. Further operating experience is required to demonstrate whether or not they will be commercially successful. The potential of using short sequences in some Ontario mills appears good, and could result in relatively low cost oxygen delignification systems since redundant washers etc could be used, The authors did not consider that there was sufficient information available to apply these short sequences in the alternative technology trains discussed on page 243.

In the early 1970s, it was proposed to use ozone to further delignify oxygen delignified pulp. Extensive research and development has led to one ozone delignification system now being under construction, and several companies, including E.B. Eddy at Espanola, are investigating ozone delignification on pilot-plant scale. Refer to Chapter 6 for further discussion.

The filtrates from washing after the first chlorination (C_d or D) stage contain chlorides so it is impractical to recycle these effluents to the recovery furnace along with the oxygen stage filtrates.

5.1.9 Peroxide and peroxide enhanced extraction

The addition of hydrogen peroxide to the E_o stage of the standard bleach plant (known as E_{op}) enables a mill to decrease the quantity of molecular chlorine applied to the pulp and also permits a reduction in chlorine dioxide use in the later bleach stages. The chlorine dioxide capacity which is released, can be utilized to increase the level of chlorine dioxide substitution in the chlorination stage. This will assist in moving the bleaching process into the well known dioxin "non detect" zone. There is also a significant (25%) reduction in AOX measured in the untreated effluent (Reid 1991).

E_{oP} is a short term cost effective method of reducing 2,3,7,8 TCDD and AOX discharges without increasing the chlorine dioxide generator capacity. Peroxide may also be used in the absence of E_o and similar environmental benefits obtained, however, this method is less cost effective than with E_o, and is rarely practiced..

This technology was not used in any of the alternative technology trains discussed in this report, since it is generally intermediate between trains 2 and 3 or trains 2 and 4. It is mentioned here primarily to demonstrate that there are alternative means of reducing AOX discharges.

E_{op} enhances the benefits mentioned on page 78 concerning alkali/oxygen extraction.

Hydrogen peroxide can also be used in bleaching sequences aimed at eliminating molecular chlorine, and toxicity of the wastewater is similar to or somewhat less than toxicity from conventional chlorine bleaching. There are other advantages since in some cases the effluents from peroxide and acid pretreatment stages can be recycled back to the recovery system, achieving reductions of 90% in colour, 40% in BOD, and finally, no chlorinated organic substances (Dugal 1981). Refer also to discussions of the *Lignox* process in Chapter 6.

The relatively high cost of hydrogen peroxide (on an oxidizing equivalent basis) has been a major impediment to its use in the past, but prices have dropped somewhat relative to other bleaching chemicals, and greater use of peroxide can be expected.

5.1.10 Substitution of molecular chlorine with chlorine dioxide

SUMMARY Chlorine dioxide can be used in place of the molecular chlorine normally used to bleach pulp. This practice improves effluent and pulp quality. For most mills it is the simplest, most widely demonstrated and lowest capital cost approach for reducing organochlorines, but does not reduce BOD, or wood extractives. Relative to a mill with neither oxygen delignification nor chlorine dioxide substitution, the latter can reduce organochlorine discharges by up to approximately 70%, if all of the molecular chlorine is replaced; oxygen delignification alone would achieve about 40% reduction in the same mill.

Chlorine dioxide is used increasingly to replace the traditional molecular chlorine in the first (chlorination) stage of the bleach plant. In the past the advantages were mostly concerned with improvements in pulp quality, but since 1 kg of chlorine dioxide can replace approximately 2.63 kg molecular chlorine, there is a net reduction in the amount of chlorine used, and a reduction in discharges of organochlorines. The principal driving force to increased substitution is AOX and PCDD/PCDF reductions, but the advantages in pulp quality remain.

Chlorine dioxide substitution is defined as the percentage of "**equivalent chlorine**" or "**active chlorine**" used in the form of chlorine dioxide in the chlorination stage. For example, a bleach plant which does not practice chlorine dioxide substitution may use 60 kg of molecular chlorine in the first chlorination stage per tonne pulp produced. If it is converted to 30% substitution, then the molecular chlorine charge could drop to 42 kg/tonne pulp, augmented by 6.84 kg/tonne chlorine dioxide. The foregoing example assumes a constant replacement factor of 2.63, which is common practice for rapid calculations. However, many authors, including du Manoir (1982) have shown that delignification efficiency improves as the degree of substitution increases, up to about 50% substitution. Pryke (1988) and other authors have concluded that the efficiency drops as substitution is increased substantially above 50%.

Figure 23 on page 129 shows the effect of substituting up to 100% of the molecular chlorine in a typical softwood bleach plant on organochlorine discharge. The bleaching chemical requirements for various degrees of chlorine dioxide substitution are shown in the curves presented by Mannisto (1991), and reproduced in Figure 12 on page 78.

Softwood kraft was bleached with 100% chlorine dioxide substitution at the Canfor, Prince George mill in 1976, because of a temporary shortage of molecular chlorine. However, this high level of substitution was not attempted by mills on a wide scale prior to the increase in public concern and regulatory authority pressure in the late 1980s. Many North American mills have run successful trials with production quantities of pulp bleached with 100% chlorine dioxide[58] in the former chlorination stage, and approximately 90 of the 150 bleach pulp mills in North America now have the necessary chlorine dioxide generation capacity to do so regularly. Approximately 45 mills have current projects to install the necessary generating capacity, or to reduce the incoming Kappa number of the pulp by some form of extended delignification, so that they will be capable of replacing all molecular chlorine with chlorine dioxide. Several authors at the May 1991 CPPA technical section meeting (including Andrews) reported mills to be manufacturing 100% substitution bleach pulp routinely.

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[58] *Many mills can run short term trials at much higher than normal chlorine dioxide substitution levels by shutting down one bleach line where two exist, or by drawing down inventory for several hours. Most mills require installation of additional chlorine dioxide generation capacity to sustain substitution levels approaching 100%.*

Substitution up to about 50% generally has little impact on chemical costs, but higher levels can increase costs markedly.

The technology and equipment required to modify and operate bleach plants at high chlorine dioxide substitution have been quite well known for over ten years, but research and development has intensified over the last few years.

The **capital installation** required to increase chlorine dioxide usage depends mostly on the capacity of the mill's existing chlorine dioxide generator. Extensive improvements in process control are usually necessary and improved chlorine dioxide/pulp mixing equipment is often required. Other modifications required to the bleach plant equipment itself are minor or nil.

Chlorine dioxide is an unstable chemical which cannot be transported effectively, so all mills prepare it on site as discussed on page 88. Several Ontario mills would have to install additional chlorine dioxide generating capacity to substitute more molecular chlorine with chlorine dioxide to minimize discharges of organochlorines. Refer to Table 12 on page 91.

All the current chlorine dioxide processes affect the **overall mill chemical balance** because they produce inorganic by-product streams which consist of sodium and sulphur in various forms, primarily of sodium sulphate and sulphuric acid. In mills using low chlorine dioxide substitution in the bleach plant, the quantities of chlorine dioxide required are such that all these by-products can be used for make-up to the pulping chemical cycle. They are added to the black liquor feed to the recovery boiler as shown in Figure 11 on page 73.

However, when high chlorine dioxide substitution is used, it may be impossible to use all of the by-products. Although it is conceptually possible to sell the excess by-products, this is rarely done, due to various practical difficulties, so they are discharged to the sewer. The authors do not consider the discharge of unusable chlorine dioxide generator by-products (sodium sulphate and sulphuric acid) to be of any environmental significance. However, the fact that the mill cannot take credit for these chemicals raises the effective cost of chlorine dioxide, which is reflected in the estimated cost of the latter that was used in this report. In recent years, the trend is towards new chlorine dioxide generation processes that discharge reduced amounts of unusable by-products.

There are a number of ways of expanding the capacity of the on-site chlorine dioxide plants and the technology is well known and available from several competing suppliers. Gray (1987) summarizes current options, and includes the relevant chemical balances and costs.

Chlorate discharges

When pulp is bleached with chlorine dioxide a certain amount of the chlorine dioxide is transformed back into chlorate (Germgård 1981). Chlorate has previously been used as a herbicide (Irensee 1973), and serious effects was reported in the receiving water at the outfall of the Mönsterås mill in Sweden when they converted the bleaching process to high chlorine dioxide substitution in the early 1980s (Rosmarin 1985). Higher algae were killed in a 12 km^2 area of the receiving waters with serious effects on the functioning of the whole ecosystem. Several studies in the laboratory, in the field, or in model ecosystems, showed that effects upon the bladder-wrack were conclusively connected to this one specific substance (Folke 1991).

At Mönsterås, this problem was minimized by changing the first bleaching stage so that 83% of all the chlorine dioxide was added prior to the molecular chlorine (D_{25}, $C_{70}D_5$). This reduced the chlorate discharge from about 6 kg/t_{90} to about 3 kg/ADt.

Chlorate will be eliminated in a biological treatment plant provided there is an anoxic zone in the design. This is normally the case using ASB, but activated sludge systems will not necessarily eliminate chlorate, unless they are designed for biological nitrogen removal, which is rare in the pulp and paper industry.

At the Mönsterås mill, an aerated stabilization basin was installed which degraded the remaining chlorate to below the detection limit (<0.05 kg/t_{90}). It is believed that anoxic conditions are required in a biological treatment system to ensure effective reduction of chlorate to chloride, and concerns have been expressed that activated sludge systems may not be capable of controlling chlorate emissions, unless they are designed for denitrification. Germgård (1989) discusses this subject further.

Fresh water ecosystems that are not growth limited in nitrogen nutrients appear to be less vulnerable to chlorate than brackish waters. The reason is that chlorate and nitrate have similar molecular shapes and that plants mistake them which gives a lethal effect when nitrate concentrations are low. However, the chlorate problem should be an environmental concern that needs proper assessment when evaluating 100% chlorine dioxide bleaching.

5.1.11 Combination of oxygen and chlorine dioxide for reduction of AOX

The individual technologies and environmental effects of oxygen delignification are discussed in the section on oxygen delignification on page 166, and substitution of chlorine dioxide for molecular chlorine in the chlorination stage of the bleach plant is discussed on page 175. Both technologies can be used simultaneously.

Oxygen delignification has been in commercial use for 20 years and has been used successfully since the late 1970s by the E.B. Eddy mill at Espanola.

High substitution of chlorine dioxide has been in operation for ten years or more, and is used increasingly around the world. Pryke mentioned in his presentation to the CPPA Annual Meeting (1988) that 4.5 million tonnes pulp per year were bleached using high substitution, and that this would increase by almost 50% during 1988, presuming that all mill modifications currently announced are completed on schedule.

Norström (1987) states that oxygen delignification is the obvious and most efficient first step, if one wishes to reduce the discharge of organochlorines, and Swedish literature in general follows this philosophy. The authors agree that this is probably true for a new mill, or one where there is an unusually good opportunity to install the oxygen delignification systems at low cost because it will eliminate the need for some other major investment in the bleach plant.

However, in the case of existing mills where BOD, colour or reduction of wood extractives is not of prime concern, there are a number of advantages in considering high substitution of chlorine dioxide, as the logical first step, since it can reduce organochlorine discharges by up to 80%, depending on the current substitution level. The principal advantage is that substituting chlorine dioxide for oxygen does not increase the load on the recovery boiler, which is critical in some mills, although of minor importance in others.

The effects of these two process modifications are additive, as shown in Figure 23 on page 129. This is based on a typical softwood kraft mill, and shows the effect of substituting various amounts of chlorine dioxide for molecular chlorine in the chlorination stage. The curve for oxygen delignification shown assumes that 45% of the lignin in the washed brown stock would be removed by the oxygen stage.

5.1.12 Chlorine free bleaching

The term "chlorine free bleaching" has become quite widely used over the past few years, but is sometimes rather loosely defined. According to Smook (1990), "chlorine free" implies that neither molecular chlorine nor chlorine compounds are used in bleaching. This is the only pulp and paper industry textbook in which the authors were able to find the term. Many buyers and vendors of bleached kraft pulp use the term "chlorine free" to imply that no gaseous, or molecular chlorine is used, although chlorine compounds such as sodium hypochlorite or chlorine dioxide may be, and normally are, used. This report uses only the terms "molecular chlorine free" or "chlorine compound free" (Refer to the Glossary for the definition).

Molecular chlorine free bleaching has been practiced by many mills in North America over the past two years, mostly for short trial periods, and it is clear that molecular chlorine free bleaching is rapidly becoming common practice, and is widely considered to be technically feasible for all, or almost all, kraft pulps including high quality market grades.

The normal approach is to carry the concept of high chlorine dioxide substitution to its limit, by replacing all gaseous molecular chlorine with chlorine dioxide, and eliminating any hypochlorite bleaching stages that exist. Oxygen delignification and/or extended cooking may be implemented upstream of the bleach plant to reduce the Kappa number of the pulp and hence the quantity of chlorine dioxide used.

Chlorine dioxide must be manufactured at the mill site, and cannot be purchased on the open market. Some mills have sufficient chlorine dioxide generating capacity to substitute chlorine dioxide for 100% of the molecular chlorine used in the first ("chlorination") stage of their bleach plants and others are currently installing the necessary equipment. Refer to the discussion on page 91.

5.1.13 Control of chloroform formation

Chloroform is produced when kraft pulp is bleached with molecular chlorine, and bleach plants which use sodium or calcium hypochlorite ("hypo") produce in the order of 10 times as much chloroform as those which do not use hypo (Crawford 1987).

Up to 20% of the chloroform produced in bleacheries using hypo is formed in the chlorination stage (Crawford 1987), particularly where an unusually large amount of molecular chlorine is used relative to the Kappa number of the incoming pulp, in order to compensate for inadequate equipment. Some of this chloroform is discharged with the caustic extraction ("E-stage") filtrate (Refer to Figure 11 on page 73).

Hypo bleaching stages were installed immediately downstream of the first E-stage[59] in many bleach plants designed before 1970, but have rarely been installed in recent years.

Crawford summarized the technology available for control of chloroform formation. Reduction, or elimination, of hypo usage is the principal approach. In many mills this would require the installation of an additional chlorine dioxide stage (tower, washer and auxiliaries) and conversion of the former hypo stage to a second E-stage. Where the mill uses the CEHDED bleaching sequence, it is normally possible to simply abandon the hypo stage and adjust the chemical dosages. The introduction of alkali-oxygen extraction discussed in Section 3.7.5 has created opportunities to produce high quality pulp without hypo.

5.1.14 Controlling PCDD/PCDF formation at source (kraft mills)

In bleached kraft mills, PCDD/PCDF belongs to the 0.1% of the AOX which is environmentally significant and can be described as polychlorinated materials (Berry 1989, 1991, Fleming 1990, Folke 1989, 1990, 1991). PCDD/PCDF's produced in pulp bleaching processes are now believed to originate from chlorination of precursor dibenzodioxin and dibenzofuran contaminants of unbleached pulp in the C-stage (Voss 1988). Two internal strategies could thus be used to control their formation (Berry 1991):

> Pre-bleaching technologies: those which lower the incoming Kappa number
> Bleaching technologies: those which reduce the concentration of molecular chlorine necessary for bleaching

Although a decrease in the incoming Kappa number will reduce the overall amount of AOX that can be formed, seemingly, the incoming pulp Kappa number is not a significant variable to reduce high-chlorinated materials such as PCDD/PCDFs. Defoamers contaminated by DBD/DBF and wood chips derived from lumber that has been treated with polychlorophenols have been identified as sources for precursors (Berry 1991), and so has compression wood in that unchlorinated DBD and DBF were found to be built into the lignin structure (Hrutfiord 1990).

Chlorine dioxide substitution has been found to reduce PCDD/PCDFs levels, especially if chlorine is added first, as Mönsterås, Sweden practices. The pulp quality and economics of chlorine dioxide substitution are not favoured when ClO_2 is added ahead of chlorine.

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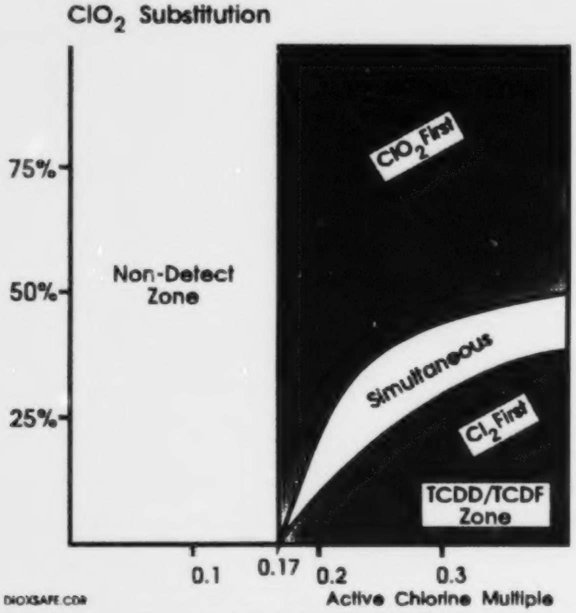
[59] *Figure 11 does not show a hypo stage.*



Source: Redrawn from Berry (1989)

Figure 37 Formation and avoidance of dioxin

Figure 37 shows the Paprican's strategy for avoiding dioxin formation during chlorination, based on practical mill observations. Bleaching with minimal PCDD/PCDF formation, and TCDD below detectable concentrations, can be achieved by a chlorine multiple at or below 0.17 without chlorine dioxide substitution or by increasing substitution to move to higher chlorine multiples (if chlorine dioxide is added after or simultaneously with chlorine). Using simultaneous addition and a total available chlorine charge of (0.22 x Kappa number)% on pulp, at least 35% substitution must be used in the formation and avoidance of dioxin. Thus it is not necessary to eliminate chlorine from the bleach plant to control PCDD/PCDF formation.

Chemically assisted coagulation after biological treatment can eliminate detectable concentrations of PCDD/PCDF (Amendola 1989), although this merely transfers the problem to solid waste and is thus not normally environmentally satisfactory. So this approach has not been further considered in this report.

5.1.15 Papricycle

Several of the process modifications to reduce organochlorine discharges at source tend to cause an imbalance in the chlor-alkali demand. The Papricycle process offers an effective, partial solution.

The Papricycle process is a variation of filtrate recycling in the bleach plant. The principle is to install an additional washer between the chlorination stage and the first caustic extraction stage, using filtrate from the caustic extraction washer, recovering some of the chemical value in it. The requirement for fresh caustic at the caustic extraction tower is reduced.

The process was developed by the Pulp and Paper Research Institute of Canada (PAPRICAN) in the mid 1980s. Berry (1988) described the process and reported laboratory results that indicated a one-third reduction in caustic required at the first extraction stage. Down stream chemical consumption is unchanged. Personal communication with Dr. Berry in early 1991 indicated that there are approximately six mill installations with the Papricycle process modification operating. Berndt (1990) described installations in two bleach lines in the Weyerhaeuser, Kamloops, BC mill and reported caustic savings of 36% in one line and "over 30%" in the other, as well as some further indirect savings in chemical costs. One of the authors visited the Kimberly-Clark mill at Terrace Bay, Ontario and was advised by mill staff that the installation had achieved the savings in caustic predicted in the literature.

The Papricycle process is considered by the authors to be demonstrated technology and has clearly gained acceptance in the industry. It is mentioned in this report only as a solution to the caustic balance problem, since it does not effect effluents directly to any significant extent.

Two recent technical developments have facilitated the implementation of the Papricycle. Increased use of chlorine dioxide to reduce discharges of organochlorines, including PCDD/PCDF, has rendered many hypochlorite (H) bleaching stages redundant. Also, several mills are replacing the second caustic extraction stage, between the D_1 and D_2 stages, by simple pH adjustment with caustic with neither washer nor reaction vessel.

The capital cost depends on the availability of a redundant washer and reaction vessel. The authors are not aware of any installations with completely new equipment. Berndt (1990) reported a capital cost of $2.1 million (presumably in 1989 dollars), and it is believed that other installations cost under $3 million.

If a new washer is required then the return on investment remains positive according to Berry and Fleming, but costs would be substantially higher.

5.1.16 Mass and energy balances for model mill

Most of the possible modifications to the kraft pulping and bleaching process which can be used to reduce discharges of pollutants at source have effects on the overall mill operation. It is essential to consider their effects on the overall mill mass and energy balances to predict their technical feasibility and probable costs. Omitting this essential engineering step has led to many failures in applying successful laboratory and pilot plant technology to full scale operations. If the overall effect of any change on the mass balance is not known, it is impossible to be sure that a process modification to solve one problem is not creating a greater environmental problem elsewhere.

The authors calculated a detailed mass and energy balance for a model mill that is typical of the more modern bleached kraft lines in Ontario. The balance, shown in Table 21, was repeated for conditions corresponding to each of the five alternative technology trains discussed on page 241. These balances were used to assist in carrying out the less rigorous but more mill specific calculations that were performed for each individual mill to predict effluent characteristics and to serve as the basis for the capital and operating cost estimates.

Table 21 Mass balance for a generic kraft mill

		Base Case	70% sub	100% sub	Oxy Delig	MCC	Oxy Delig +MCC
	Train –>		K1	K2	K3	K4	K5
Bleached production	ADt/day	1,000	1,000	1,000	1,000	1,000	1,000
Chip feed	ODt/day	2,447	2,447	2,447	2,450	2,449	2,602
Additional wood	kg/tonne		0.0	0.0	3.0	2.0	155.0
Knot and screen rejects	%	2.5	2.5	2.5	2.5	0.5	0.5
Digester yield	%	45.3	45.3	45.3	45.3	43.2	43.2
O_2 delign shrinkage	%	n/a	n/a	n/a	2.7	n/a	5.8
Bleach plant shrinkage	%	7.5	7.5	7.5	5.0	5.0	5.0
Overall yield	%	40.9	40.9	40.9	40.8	40.8	38.4
Brown stock washer dilution factor		2.8	2.8	2.8	2.8	2.8	2.8
Salt cake loss	kg/tonne	2.7	2.7	2.7	5.1	2.6	5.2
Carryover organics	kg/tonne	0.4	0.4	0.4	1.3	0.3	2.1
C_d Cl_2 substitution	kg/tonne	20.7	53.6	56.0	30.0	29.0	19.0
ClO_2 substitution	%	57.0	70.0	100.0	100.0	100.0	100.0
Total equivalent Cl	kg/tonne	95.7	98.6	101.0	81.0	71.0	65.0
Total liquor Cl/Kappa	ratio	3.3	3.4	3.5	4.5	4.7	6.5
Total oxidizing eq.	ratio	106	109	111	123	81	101
Acid sewer	cu m/tonne	38.8	39.2	40.1	38.4	38.1	37.7
Alkaline sewer	cu m/tonne	18.5	18.5	18.5	18.4	18.4	18.4
Weak black liquor solids	%	16.7	16.7	16.7	16.8	17.0	17.5
Strong black liquor (62%)	kg/min	1,245	1,245	1,245	1,300	1,284	1,438
Strong black liquor HHV	Kcal/kg	3,808	3,808	3,808	3,756	3,837	3,800
Boiler heat input	GJ/day	28,583	28,583	28,583	29,438	29,703	32,945
Boiler heat input change from base case			0.0%	0.0%	3.0%	3.9%	15.3%
Steam generation	tonne/hr	309	309	309	319	324	361
Steam generation	t/tonne pulp	7.4	7.4	7.4	7.7	7.8	8.7
Additional steam	t/tonne pulp		0.0	0.0	0.2	0.4	1.2
Slaker feed (solids)	kg/tonne	993	993	993	1,030	999	1,094
Kiln Feed (solids)	kg/tonne	565	565	565	594	570	632

All continuous digesters. These balances do NOT use anthraquinone to modify pulping yield.

5.1.17 Caustic/chlorine balance

Until very recently Sodium hydroxide (caustic) had to be produced in a fixed ratio to molecular chlorine by all the processes in use on an industrial scale. The pulp industry normally purchases these two chemicals in stoichiometric ratio (commonly known as "ECU " or Electro-Chemical Unit).

Oxygen delignification processes use sodium hydroxide but no molecular chlorine, and increased use of chlorine dioxide substitution reduces molecular chlorine consumption to a greater extent than caustic as a result. The industry faces a major change in caustic supply conditions. Concerns have frequently been expressed over the 20 years since oxygen delignification and high chlorine dioxide substitution became demonstrated technology that it could become impossible to operate a high proportion of bleached kraft mills with these "low pollution" technologies.

However, combinations of technical developments and market forces are providing solutions. One is for mills using oxygen delignification to use oxidized white liquor as alkali supply to the oxygen stage, as shown in Figure 32 on page 168. This is universal practice in existing installations, but does impose an additional load of approximately 5% on the mill's recausticizing/lime kiln cycle, also shown in Figure 32. Other solutions include the Papricycle process mentioned on page 180, or replacement of sodium hydroxide make-up in the pulping cycle with sodium carbonate. The latter practice is not uncommon (Berndt 1990). Lindberg indicated that the break-even cost for changing from caustic to sodium carbonate occurred in one US mill when the caustic price rose to US$315/tonne, while the sodium carbonate price was US$150/tonne.

Three major chemical supply companies (FMC, Tenneco and General Dynamics) have recently commenced production of sodium hydroxide by causticising sodium carbonate, using a process which is essentially the kraft pulp lime kiln/recaust loop shown in Figure 8.

In 1985, the pulp industry purchased about 45% of the chlorine manufactured in Canada; whereas in 1970 it was the predominant user of molecular chlorine. In the past few years, this trend has accelerated to the point that a number of small chlorine producing plants have ceased operation. At the time of writing, the authors estimate that the Canadian pulp industry consumes about 33% of the Canadian chlorine production and 66% of the caustic production. The US pulp industry consumes about 15% of the chlorine produced in the US, and 22% of the caustic, so the move away from chlorine in the pulp industry will presumably have less effect on the overall caustic/chlorine balance.

5.1.18 Sodium based sulphite mills

In practice there are few major differences between the environmental aspects of a true NSSC mill and a high-yield or ultra high-yield sulphite mill. They both apply sodium sulphite as a cooking liquor and both use a refiner to beat the pulp after cooking. The NSSC pulp is traditionally sold for corrugating medium, and the high-yield sulphite pulp is normally used in connection with a newsprint production to add strength to the groundwood. Because the NSSC pulp is used for corrugating medium, brightness is not an issue, and many NSSC mills have changed from a sodium sulphite/carbonate process to pure sodium carbonate (soda process). Brightness is more important for the high-yield sulphite process, so the soda process is not an option in this case.

The dirt content of the final product is less important for corrugating medium that for other grades of paper normally made by high-yield sulphite mills. This lowers the capital cost of improving in-plant process recycles to the point where the only effluents are clean cooling water and the strong black liquor which can be incinerated by proven equipment.

For many years the cross recovery of spent liquor was practiced when the mill included a kraft pulp operation. The spent sulphite liquor was pumped to the kraft mill evaporator station and the soda and sulphur was used as make-up chemicals in the kraft mill. Isolated NSSC mills and high-yield sulphite mills generally discharged black liquor to the receiving waters, unless environmental constraints prevented the practice. Today cross recovery is little used since the environmental pressure on the kraft operations have resulted in process changes largely eliminating the need for make-up chemicals. The only cross recovery operation in Ontario, at CPFP, Thunder Bay, was shut down in April 1991, and the manufacture of sulphite pulping discontinued.

If the NSSC mill site is not in the vicinity of a kraft mill, a practice has been developed in which the spent liquor is incinerated in a fluidized bed reactor. Fluidized bed incineration systems are usually based on pulp washing efficiencies of about 75%, but it is a delicate operation due the limited heat value of spent liquors from semi-chemical operations as compared to chemical pulps. A well designed system can operate exothermically, but the complexity and capital cost can rarely be justified. The product, sodium sulphate, is then sold as a powder to the kraft mill for chemical make-up. An example of such an operation is the Weyerhauser Mill in North Bend, Oregon.

An NSSC mill, Green Bay Packaging Inc. in Green Bay, Wisconsin, was replaced by a recycle linerboard operation in early 1991, after over 10 years of operating with under 1 kg BOD/tonne product without any external effluent treatment.

If the NSSC mill converts to the soda process the incineration product becomes sodium carbonate which directly can be reused in the pulping process. There are many examples of mills that have used a pure soda process for the purpose of recovering cooking chemicals. These mills include Papier Cascades in Cabano, Quebec, Nekoosa Packaging in Tomahawk, Wisconsin, Stone Container Corp. in Ontonagon, Michigan[60] and Sonoco Products Co. in Hartsville, South Carolina among others.

The 300 TPD Cabano mill has operated a liquor incineration/recovery system based on a Copeland fluidized bed furnace successfully since 1975. Since a pulp washing press was installed several years ago, the system has operated with 90 to 95% recovery of organics. The remaining BOD is treated externally.

None of the Ontario corrugating medium or sodium based high-yield sulphite mills have installed recovery systems. Technically there is no hindrance to doing so, but the capital cost is quite high, and other options may well prove more cost effective if environmental constraints force these mills to a better effluent quality.

In Europe, NSSC mills have virtually all been shut down or converted to other processes, partly because corrugating medium is manufactured from secondary fibres. In the USA almost all former NSSC operations are now soda based.

In Europe, the US and Western Canada, newsprint mills based on groundwood pulp use market kraft pulp for strength improvement. Since the 1970s, there has been a trend to convert the groundwood mills to TMP/CTMP to eliminate the need for market kraft pulp. An increasing number of these mills use deinked secondary fibres. A few use low-yield magnesium base sulphite pulp in which case waste liquor recovery is somewhat simpler. However the relatively small scale of sulphite pulping operations in Ontario mills is an obstacle to effective sulphite liquor recovery.

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[60] *This mill bought a Copeland fluidized bed reactor in 1990. The total cost of this installation was 10.2 million US$ (1989) The washing efficiency is 80 to 85%, sometimes up to 88%. Water use is 17 m^3/tonne and the raw waste loads are 24.5 kg/tonne BOD and 17.0 kg/tonne TSS. Effluent treatment consists of primary clarification, activated sludge using diffusion aerators and secondary clarification. This reduces the effluent loads to 0.9 kg/tonne BOD and 1.5 to 2.0 kg/tonne TSS.*

There are other true sodium based sulphite recovery techniques available, e.g. the Billerud, Rauma Repola, Stora or Tampella recovery systems. These are closely related to kraft recovery systems in that they apply reductive incineration and convert sulphide to sulphite afterwards. The Billerud process is based on pyrolysis of the black liquor, and there is one such system still in operation at the Mead Corp. NSSC pulp mill, in Stevensen Alabama. However these techniques are not relevant to the relatively small, high-yield sulphite pulp mills in Ontario.

A Copeland fluidized bed reactor was purchased and installed in Ontonagan, Michigan in 1989 at a cost of US$10.4 million (Cdn$12.4 million at mid 1991 rate of exchange), for a 600 tonnes/day corrugating medium mill. The necessary washing and evaporator equipment was already installed at the mill.

In summary, although fluidized bed incineration of sodium based sulphite spent liquor is technically possible and is currently practiced in a few mills, it is not attractive due to difficulties in selling the recovered sodium sulphate. This problem is expected to become more difficult, if not insurmountable. The only option for corrugating medium manufacturers wishing to install a black liquor recovery system is to convert to a sulphur-free soda process. An alternative approach to disposing of the spent pulping liquor is to use it as a binder to control airborne dust and enhance the surface of gravel roads, as currently practised by Domtar at Trenton.

High-yield sulphite operations feeding newsprint mills are left with the options of changing to a low-yield magnesium base with red liquor recovery, substituting the sulphite pulp with market kraft or deinked secondary fibres, or building a large biological treatment plant.

5.1.19 Closed cycle paperboard mills

When Green Bay Packaging Inc. operated their NSSC mill at Green Bay, Wisconsin, they did so with almost 100% closed operation (< 0.5 kg BOD/tonne), without biological treatment from the late 1970s until 1990, when the mill was converted to use secondary fibre instead of virgin pulp. The fluidized bed reactor destroyed all organics and the sodium sulphate was sold off site. Excessive heat was a major problem in operating the closed mill, and the result was a white water system running at 75 to 70 deg C. The product, corrugating medium, was sold with a substantial amount of dissolved solids (approximately 6%) in it, but that did not appear to affect its use or marketability. A competing mill in Tomahawk, Wisconsin had a soda process running, but with a water use of 22.5 m^3/tonne. Wisconsin was short of linerboard which was imported from the south. For market reasons, it was decided to change the product at Green Bay from corrugating medium to linerboard. US$35 million was invested mainly in paper machine conversions to change the product line, and from early 1991 Green Bay started a secondary fibre linerboard operation with a production of 450 tonnes per day. At the time of writing, they discharge 1100 m^3/day to the sewer, but that is expected to cease completely in the near future. It should be noted that the investment was made for market reasons and not for environmental reasons.

Zero effluent has also been achieved in several steps by the Grenaa Papfabrik AS in Grenaa, Denmark, a mill producing 160,000 tonnes per year of corrugating medium and linerboard from secondary fibres. In 1976 this mill began to recycle white water from the Fourdrinier section of the paper machine, reducing the water consumption from 50 m^3/tonne to 35 m^3/tonne of product. In 1978 they started to use cooling water for sealing purposes, and in 1983 they converted to mechanical seals, reducing the water consumption to 15 m^3/tonne. Installation of flotation clarifiers and several intermediate water storage tanks were the final means of reaching zero effluent. Figures 38 and 39 illustrate the achievements over the years, and **reinforce the frequently repeated statement that zero effluent can best be attained by a long term program**.

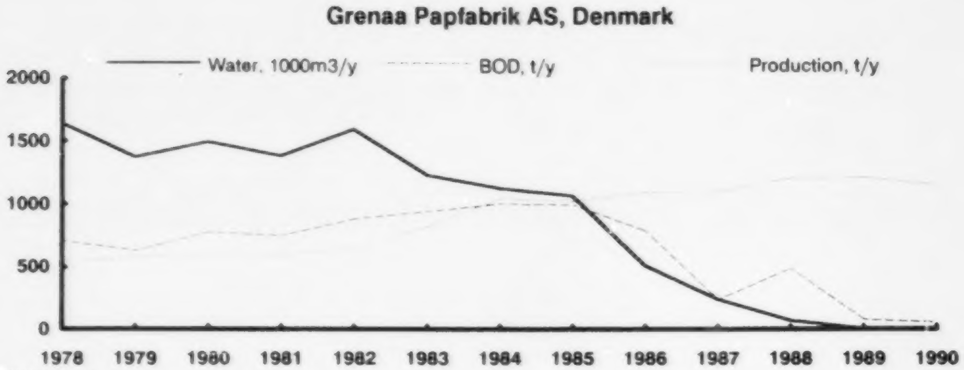

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Figure 38 Evolution toward zero effluent at Grenaa Papfabrik AS, Denmark

The main problem of operating with zero effluent in the Grenaa mill was microbial growth enhanced by starch in the filler. This lead to the formation of organic acids and thus corrosion and potential health problems. Both problems were solved by a combination of stainless steel materials and the use of biocides (presently nitro-bromo-propandiol). The total cost of converting from 50 m³/tonne to zero effluent has not been calculated because it has been an evolutionary process. When mill management was faced with demands for biological treatment at a new municipal treatment plant at the cost of 35 million DKK ($7 million) in 1987, they decided to close up the mill water cycle entirely. The detailed cost analysis was not made available to this study.

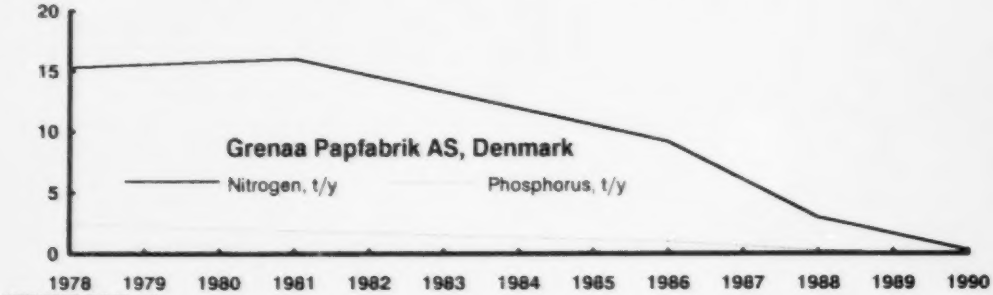

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Figure 39 Nutrient discharge reduction 1978-1990 for Grenaa Papfabrik AS, Denmark

5.1.20 White water management

SUMMARY Environmental legislation and rising energy costs have led to significant reductions in process water consumption during the last 40 years in pulp and paper mills. There is a need to recognize that this has not generally been the case in Canada partly due to regulatory requirements discouraging water conservation programs, because toxicity tests which have been the cornerstone of much of the regulatory activities, are based on concentration rather than toxicity emission rates (see TEF and TER in the Glossary). It is standard practice to recycle water within a mill. The degree of recycling, however, varies widely.

The management of white water has several objectives including to:

Reduce water consumption
Reduce heat losses
Save raw materials
Provide a consistent quality water to the manufacturing process
Avoid contamination of a sensitive system with foreign materials, and of course
Reduce the load on the treatment system (and environment).

There are several approaches to accomplishing these goals with some of the important steps as follows:

Keep paper mill and pulp mill waters separate
Use savealls to recover fibre and fillers and to condition water for use as shower water
When viable, use chemical assistance to improve filler and fines retention
Use mechanical devices, such as in-line screens, to recover useable materials, and clarify shower water
Provide well controlled instrumentation for supply segregation, flow uniformity, and water quality
Recycle white water as the main source of dilution water outside the headbox loop
Use filtered white water in most showers
Use temperature controlled filtered white water as vacuum seal pump water
Return contaminated white water streams to processes nearer their origin, thus avoiding unnecessary cleaning of streams in savealls.

The cost of treating an effluent stream is high. All of the approaches should be reviewed with the objective of reducing water consumption so that there is less effluent to treat and less incoming fresh water to condition.

Reduction of the fresh water demand in the paper mill may be achieved either through equipment modification (low flow rate showers, heat exchangers etc.), which results in reduced fresh water demand, or through recycle of white water either within the paper machine or to some other process (integrated pulp and paper mill).

White water may also be used outside the mill in the bleach plant or at the pulp mill, or even be recycled to the raw water treatment plant for further treatment and use as process water. However, measures must be taken to ensure that no unwanted materials are transferred in this water, e.g. metals, defoamers etc.

Problems encountered in recycling and/or reusing white water include

Increased white water solids:

Results in poor drainage and increased drainage aid demand.

Increased corrosion:

No single water quality characteristics accounts for the corrosion rate. However, increased fresh water usage has often been shown to decrease corrosion rates by diluting dissolved solids. Increased conductivity generally correlate with increased corrosion rates.

Shower nozzle plugging:

May be minimized by use of filtration devices; selection of appropriate nozzle orifices and operating pressures; blending fresh water with white water; keeping velocities in pipes high to prevent settling; and an effective maintenance program.

Increased deposits formation:

Results in plugging of filters, screens, wires, and forming fabrics and affects product quality. May form scale as well as deposits of pitch and slime. Scaling is normally due to magnesium, calcium, and sometimes barium sulphate. A number of additives may minimize scaling, but problems of deposits formation and their solution are very site specific.

Biological growth:

When the nutrient concentrations in white water increase this leads to microorganism growth. Elevated temperatures (>50 deg C) may prevent this, but as it may not be possible to keep this temperature in all parts of the machine, thermophilic bacteria growth may result. The control of microorganisms is site specific.

Elevated white water temperature:

Affects scaling, corrosion rate, and biological growth, in addition to reducing the performance of vacuum pumps (due to elevated vacuum pump sealing water vapor pressure).

Product quality impacts:

Questions have arisen regarding paper properties such as strength, opacity, and brightness. Sizing is also a subject of concern; some mills have reported improved sizing, while others have reported problems with internal sizing as a result of closing white water systems.

5.1.21 Effluent flow reduction

SUMMARY The reduction of effluent by means other than process changes can have a major impact on the final effluent volume. One important area is recycling process water from all sources in addition to the usual reuse of white water. It is important to use a source of recycled water that meets requirements rather than always using fresh process make-up water. The avoidance of intentional and accidental spills further reduces the hydraulic load on the effluent treatment facilities.

Water recycle

The foregoing section discusses the management of white water while this section covers the use of water from all sources. In principle the reuse of water should be carried out as close to the source of the water as is practical. For example, paper machine white water is used for on-machine applications first, with any excess available for distant points such as in the pulp mill. A second principle is to use the lowest quality water available that will adequately do the job. By applying these principles in a reasonable way, the wastewater discharged to the effluent treatment system will be minimized.

The recycling of water around the paper machine is important not only for the conservation of water but also to minimize losses of materials and energy. Recycling water in other areas has the same benefits, but generally the important benefit is the reduction in fresh water make-up which in turn means less water to be treated before discharge to the receiving water.

Frequently fresh water is used around the papermaking area in applications where a lower quality of water would do just as well. One example is the paper machine vacuum pumps. These pumps are used to apply a vacuum to suction press rolls, de-watering devices in the paper forming area, and felt cleaning equipment in the press section. Fresh, or raw water, is not required for this application. These vacuum pumps traditionally use liquid ring seals and discharge large quantities of lightly contaminated effluent. Up to 20 m^3 of water per tonne of product can be discharged (NCASI 1983).

Using filtered white water at a temperature and flow that complies with the manufacturer's requirements should provide opportunities to reduce the effluent from this source. A few mills use dry rotary turbine vacuum pumps and have virtually eliminated this source of effluent.

Other applications may involve cascading cooling water through bearings then using the water in a related process area. Lightly contaminated water can be used for dilution and/or sluicing purposes rather than fresh water in other areas. There are many similar examples that can be identified.

Spills

Accidental spills are defined as excessive discharges to the environment caused by abnormal operating conditions. These spills may be the result of poor monitoring strategy, of inadequate control equipment, or simply of inattention. As a mill or process is closed up, these spills take on greater significance. An in-plant spill control system greatly assists in recovering toxic materials, and in stabilizing toxic and hydraulic loads to the external effluent treatment system. Spill control systems normally involve contaminant measuring devices; for example, conductivity or pH meters, etc, and they also require to provide alarms for upset conditions. Instrumentation to assist in supervision of flow diversion controls, and collection vessels and ponds is required.

Cleaning of large tanks and smaller vessels including drums, etc. leads to dumping the washings either to the process or the effluent system. Wash-up hoses are another form of intentional spills. Fresh water is frequently used when excess process water from various sources would be adequate. The latter must be used with caution if the recycled water promotes slime growth or other slippery conditions. These intentional spills can cause upsets in the treatment system or undue loads on internal recovery equipment. Overloaded equipment can cause an excess to be dumped to the external treatment areas.

5.2 External Treatment Technologies

SUMMARY External treatment is utilized as a supplement or an alternative to discharge control at source. It may involve a range of physico-chemical and biological measures. Primary treatment involves removal of suspended solids, normally in a gravity clarifier. All Ontario mills apply this technique. Secondary treatment removes soluble organic materials, normally by biological treatment which primarily removes BOD, and acute toxicity. Seven Ontario mills have secondary treatment, one of which is anaerobic only. Tertiary treatment can involve different physical chemical techniques, e.g. granular filtration or chemically aided coagulation to further reduce TSS, phosphorus and others.

This section of the report is concerned with external treatment of effluent to minimize discharges which may cause water pollution.

Water pollution is the introduction into a body of water those substances whose character and quantity so alter its natural quality in a manner that will influence its aquatic life, impair its usefulness or render it offensive to the sense of sight, taste or smell. In most cases the effluent discharge reduction technology discussed in this report will reduce water pollution, but in some cases a trade-off should be considered.

Alterations of water quality are inevitable. Systems not influenced by humans experience water quality changes with time, e.g. natural eutrophication of a lake or stream. Humans are just an additional factor in the changing dynamic system often termed the "balance of nature". Humans cannot prevent change, but they can try to ensure to that their actions promote beneficial change compatible with the protection of our environment, and minimize degradation due to industrial, government, domestic and recreational activities.

5.2.1 Pollution sources

Numerous sources of water pollution exist. The types of undesirable discharges most common in the pulp and paper industry, and which can be reduced substantially in conventional external treatment systems include:

Suspended solids (TSS) are normally fibre, biological solids or ash from mill production operations. Some TSS will blanket the bottom of recipient water with resultant upset of receiving water biota unless the settleable solids are removed by treatment before discharge.

Soluble organics exert biochemical oxygen demand (BOD) causing depletion of dissolved oxygen (DO) with resultant limiting of the uses of the recipient for other beneficial purposes, or for aquatic life. COD is also a measure of dissolved organics, and included both the biodegradable and non-biodegradable fractions.

Acute lethality, or **toxicity**, to fish and *Daphnia magna*. This parameter has been used with trout as the test organism in Canada for over 20 years to regulate and evaluate pulp and paper mill effluent discharges, but is much less used in other countries. Unless otherwise noted, the statement that a particular effluent is "toxic" normally refers to its failure to pass the 96 hour LC_{50} test for acute lethality.

Most of the biological treatment systems installed in the Canadian pulp and paper industry were installed primarily to reduce acute toxicity, with BOD and suspended solids control as secondary objectives.

Priority pollutants or **"unconventional" pollutants** represent a diverse range of substances, both natural and man made, that may restrict or eliminate use of the waters. These are an increasing concern because of the diversity and magnitude of the possible effects, and the inability of the natural ecosystem to degrade a small but significant proportion of them. Typical compounds within this category of concern in the pulp and paper industry include: AOX, PCDD/PCDF and other chlorinated compounds.

While external effluent treatment systems can reduce discharges of some "priority pollutants" substantially, others are effected very little by passing through an effluent treatment system. **It is essential to recognize that to-day's biological treatment technology was developed for BOD and toxicity control, and that any reductions in the "unconventional" pollutants are largely gratuitous.** In most cases there is not yet sufficient knowledge available to optimize biological treatment for removal of the unconventional pollutants.

These pollutants can either be eliminated at their point of origin in the pulp mill production process, as discussed previously or with external waste treatment. Many factors, including technical and financial considerations, may influence the choice of the optimum approach to remove pollutants. These decisions are often mill specific and represent considerable technical challenges.

Nutrients (phosphorus and nitrogen) are of increasing concern, with phosphorus being the more important in Ontario. **The discharges of phosphorus and nitrogen from pulp and paper mills will generally be increased by external biological treatment**, since these substances have to be added to the effluent to attain efficient BOD removal.

5.2.2 Wastewater treatment classification

Wastewater treatment is usually classified as follows:

Primary treatment involves removal of total suspended solids. Normally this is achieved in a gravity clarifier or sedimentation basin. However, alternative processes include dissolved air flotation (DAF) and screening. Preliminary treatment, involving grit removal for inorganics and bar screening for removal of larger objects entering the wastewater treatment system, normally precedes primary treatment.

Secondary treatment implies removal of organic materials from mill effluents, particularly BOD and substances acutely lethal to fish and *Daphnia magna*. Biological treatment is by far the most common method of secondary treatment.

Tertiary treatment involves unit operations other than primary or secondary treatment, normally applied to the effluent from a secondary treatment system.

5.2.3 Biological treatment principles

Biological treatment systems are designed to create suitable conditions for the development and maintenance of microorganisms which convert organic pollutants in the effluent stream to a more desirable or harmless form.

Basic principles of biological treatment processes are discussed below, followed by descriptions of practical processes.

Microbiology of the treatment system

Treatment plant microorganisms include bacteria, fungi, protozoa, rotifiers and algae. Algae growth is often insignificant in pulp mill effluents because the dark colour of mill effluents effects light penetration.

The only existing low cost method for removing some types of organic matter such as lower fatty and hydroxyl acids, sugars, alcohols, ketones, and similar compounds from dilute solutions is to use them as a substrate for microorganisms. This is possible through microbiological action which converts them into cell substance or oxidizes them to CO_2 and water. The organic matter (substrate) may be either soluble or insoluble. Soluble BOD is assimilated directly through the bacterial cell membrane (wall). Insoluble organics removed by microorganisms must first be solubilized via exoenzymes secreted by the microorganisms before the substrate can be metabolized.

Under aerobic conditions this involves the utilization of oxygen by the bacteria responsible for the process. Part of the organic matter in the substrate is used by the microorganisms for fuel for energy and part is used to provide building components to construct new microbial protoplasm (synthesis). Concurrently with the energy and synthesis reactions is a process called endogenous respiration, which is generally thought of as a maintenance mechanism of the microorganism.

The insoluble cell substance, or microbial protoplasm, produced can be separated from the liquid waste. Disposal of the solids produced can be reduced by microbial decomposition through the process of endogenous metabolism. The extent and reaction rate in which the energy, synthesis, and endogenous metabolism steps are carried to completion depends upon the environment imposed by the waste itself and by the mechanical aspects of the system.

All processes employing biological oxidation follow a pattern similar to that occurring in the self-purification of streams. In this phenomenon, the velocity at which the reaction takes place depends upon the energy exerted within the system and the substrate concentration gradient between the liquid waste and the active biological organisms. Microbial colonies of suitable character to effect rapid biological oxidation can be developed in concentrated forms. These include systems such as slurries (activated sludge), attached slime coating on surfaces (trickling filter media), dispersed growths (aerated stabilization basins or ASBs) or a combination of dispersed and attached growth (rivers and streams).

The operating temperature of biological treatment systems should normally be below 38 deg C if maximum efficiency is desired. Short retention time systems (under about 48 hours) in the pulp and paper industry often may require cooling equipment. The current trend to reduce effluent flows by extensive in-plant recycle generally raises effluent temperatures, but may be offset by energy conservation measures within the mill, which tend to lower effluent temperatures.

Aerobic versus anaerobic treatment

The availability of oxygen to the microorganisms in the principal reaction vessels determines whether a wastewater treatment process will be aerobic or anaerobic. If adequate molecular oxygen is present, the bacteria present will always metabolize aerobically. If molecular oxygen is absent, the conditions are anoxic. Aerobic systems are by far the most widely used secondary wastewater treatment and include oxidation basins, aerated stabilization basins (ASB), trickling filters, and activated sludge treatment (AST).

The absence of dissolved oxygen in wastewater creates anoxic conditions. In this case, the metabolic patterns of the microorganisms are such that the oxygen comes from the organic matter being decomposed. The conditions created during anaerobic reactions often make the water unsatisfactory as a natural habitat for normal aquatic life and the wastewater often becomes black and odourous due to the anaerobic decomposition products. In general, the rate of organic matter decomposition is slower under anaerobic conditions than would be aerobically.

There has been increasing interest in anaerobic treatment processes for pulp mill wastes in recent years, because they produce less waste sludge than AST, require much less electrical energy, and can produce economically usable quantities of fuel gas under suitable conditions. Some designers have claimed that anaerobic treatment is a necessary pre-treatment of high strength wastes, but this has been disproved by the success of many aerobic systems in treating pulp mill effluents containing several thousand mg/L BOD. (The Alberta Newsprint mill discussed in Appendix C is one example). Other aerobic systems successfully treating concentrated wastes in Canada are at Millar-Western in Whitecourt, Alberta (raw effluent BOD occasionally over 5,000 mg/L, average over 3,000 mg/L) and the Donohue CTMP mill at Matane.

Anaerobic treatment is most effective in effluents where the concentration of organic pollutants is high (BOD over 1000 mg/L). It is often used to treat selected high strength waste streams. The excess biomass generated by anaerobic treatment is less than one-third of the quantity that would be generated by an AST system, reducing sludge disposal costs.

Anaerobic effluent treatment systems have been used successfully in the food industry, but their track record in pulp mill installations has been mixed. There are four systems operating in Canada at the time of writing. At the CTMP mill at Quesnel River Pulp, in Quesnel, BC extensive modifications to the original system were required, doubling the originally estimated capital cost of $10 million before reasonably satisfactory operation was attained. This system is followed by aerobic treatment. Both the Sturgeon Falls, Ontario and the Lake Utopia, New Brunswick installations are currently working out start-up problems at least a year after original commissioning. The system at Bathurst, NB is reported to be operating well, and recovers significant quantities of gas which is used in the flash dryer for the pulp.

The authors did not include anaerobic treatment systems in the alternative technology trains because:

They are not yet sufficiently mature to permit prediction of costs.

Several mills consider that the danger of an extended re-start period after an accidental loss of viable biomass would be unacceptable in an age of increasingly rigorous enforcement of effluent discharge regulations.

Rather than being an alternative effluent treatment process to aerobic systems, the anaerobic processes are a means of potentially reducing the operating cost of an aerobic effluent treatment system.

Waste characteristics

The dissolved BOD fraction of pulp and paper mill effluents consists largely of wood extractives and cellulose decomposition products which are readily amenable to bacterial attack. Industry practice has shown that all the dilute waste from pulp and paper manufacture can be treated biologically if conditions for the development of suitable microorganisms are established. The wastes include weak wash water, evaporator condensates, bleaching waste, excess white water, woodyard wastewaters, and dilute spent cooking liquors. Factors affecting the microorganism's development include pH, temperature, oxygen supply, and the presence of sufficient nutrients including nitrogen and phosphorus in an available form (such as ammonia and phosphoric acid).

The foregoing general discussion of biological treatment applies to all aerobic systems, and further specific points are discussed below in the descriptions of the commonly used processes. Anaerobic processes are still developing and may show promise for high strength wastes. The Stone-Consolidated Inc. mill at Bathurst uses an anerobic system successfully to reduce overall effluent treatment costs. They are discussed in Appendix G.

5.3 Biological Treatment Processes

There are many forms of biological treatment used to treat municipal and industrial effluents, and most have been investigated for at least one mill. Activated sludge treatment (AST), a "high rate" process, and aerated stabilization basins (ASB), a "low rate" process dominate the field in the pulp and paper industry. They seem likely to continue to do so. There are approximately 600 installations in the North American pulp and paper industry, and increasing numbers are being installed in Scandinavia and other pulp and paper producing regions.

5.3.1 Activated sludge treatment (AST)

SUMMARY Activated sludge treatment (AST) is a widely used biological process normally applied to primary treated effluents. The principle is based on the building of a settleable sludge of microorganisms grown on the soluble materials in the effluent. The sludge is recycled within the process and excess sludge is concentrated and then incinerated or landfilled. The successful operation of an AST system involves the control of the varieties of microorganisms present in the reaction vessel, the food to microorganism ratio and the sludge age. Energy and chemical requirements for sludge handling make this process more expensive per tonne of removed BOD than an ASB system. AST can achieve lower BOD and TSS than aerated stabilization basins, but generates significant quantities of waste sludge and discharges higher quantities of nutrients than an ASB.

A number of high rate biological treatment processes are used for treatment of municipal and industrial wastewaters. The activated sludge process, developed around the turn of the century in England, is the only high rate biological treatment process that is widely used for treating pulp and paper mill wastewaters. Rotating biological contactors (RBC), trickling filters, extended aeration and many variations of the activated sludge process have all been installed. Most of the RBCs have been abandoned.

These processes operate with very high concentrations of microorganisms, and relatively short hydraulic retention times. BOD reduction is quite rapid, with treatment completed in 2 to 24 hours, resulting in compact installations. Generally, the higher the reaction rate, the more suspended solids are produced.

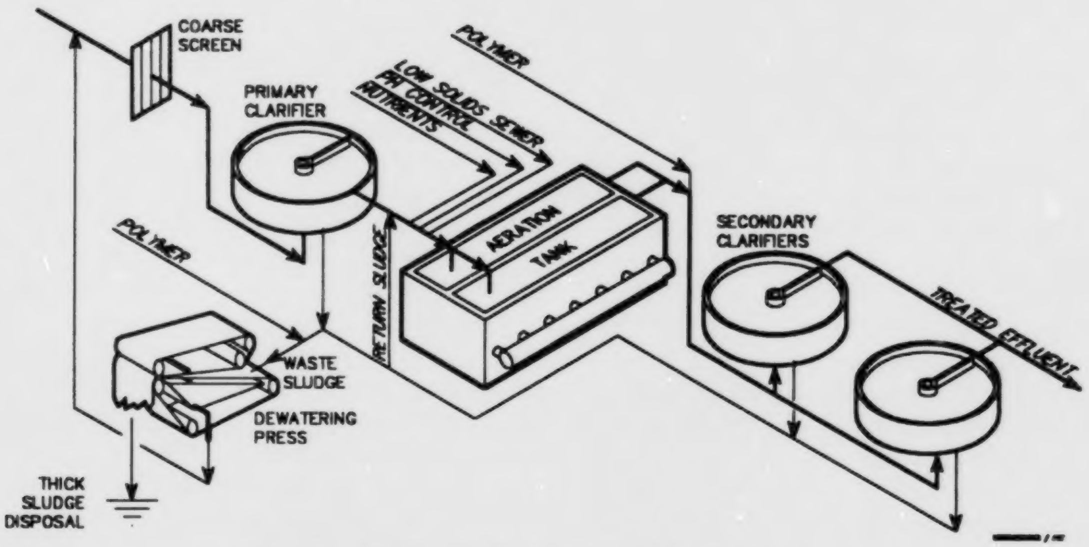

Figure 40 Flowsheet of typical activated sludge system

A typical primary effluent treatment system followed by an activated sludge system is shown schematically in Figure 40 and its operation can be described as follows.

The main effluent stream passes through a coarse screen, to a primary clarifier where the settleable solids are removed by simple sedimentation. The pH of the clarified effluent is adjusted, if it is not already close to neutral, and recycled sludge is added. After adding the necessary nutrients, the effluent flows into an aeration tank where it is violently agitated and oxygen is supplied, normally in the form of air, but industrial grade pure oxygen is sometimes used. In the aeration tank a mixed population of bacteria and other microbiological life develops, feeding on the organic substances, oxygen and nutrients. The effluent then flows to the secondary clarifiers, where most of the biomass settles, and then the clarified effluent is discharged.

Some of the sludge produced is recycled to the aeration tank as shown. The excess sludge, in the order of 0.4 to 0.5 kg solids/kg BOD removed, must be dewatered and disposed of effectively. The quantity of waste activated sludge handled is a function of the solids retention time (sludge retention time) in the aeration tank and the food to microorganism loading ratio. A long sludge retention time and low F:M will result in the least quantity of waste activated sludge. The waste activated sludge is typically extracted from the treatment system for subsequent disposal at around 1% consistency. This requires energy, chemicals and a variety of complex equipment. Chemicals may represent one-third of the operating cost of the effluent treatment system, but are frequently overlooked or seriously underestimated in feasibility studies and other predictions of environmental compliance costs. The most widely used mechanical dewatering technologies are vacuum filters, belt presses and centrifuges.

During the past decade mills have reduced their losses of long fibre to sewer which had previously served as a drainage aid in sludge dewatering. Today's typical sludge from AST systems contains a preponderance of fines and biological cells making dewatering difficult. Consistencies of 25% to 30% are reported on belt filters for systems where the activated sludge is mixed with fibre from woodroom waste in ratios from 6:1 to 2:1. High polymer additions are required to attain these consistencies when the lower quantities of primary fibre are used. Where a mill has sufficient primary sludge to attain the 6:1 ratio, there are probably excessive fibre losses from the production operations. Much of the water included with the biosolids in un-dewatered sludge remains attached to the biosolids, and will eventually have to be evaporated at the same fuel cost if the sludge is incinerated, whether mixed with primary sludge or not. Solids dewatering and disposal can represent the largest cost of operation of an activated sludge plant.

Within the past five years new generation long bowl screw press technology has demonstrated superior dewatering capability when applied to the mixed primary and waste activated sludges found in the pulp and paper industry (Maltby 1991). This new technology will produce a cake having a solids content up to 40%, with polymer additions in the order of 10 kg/dry tonne sludge. A survey by Maltby (1991) indicated that most mills dewatering mixed primary and secondary sludges used between 5 and 15 kg polyelectrolyte per tonne sludge. One mill was reported to be using 70 kg/tonne (personal contact with Mr. Maltby indicated that this was diluted polymer, and that the actual quantity of dry polymer was unknown). There are a wide variety of polyelectrolytes on the market, with costs from a few dollars per kilogram to about $12/kg, so total operating costs are also variable. It would not be unusual for a mill to spend over $50/tonne dry sludge for these chemicals. Assuming the normal sludge generation rate of about 1 kg/kg BOD removed (total of primary and secondary sludges) this is equivalent to about $0.05/kg BOD removed. This is approximately equal to the electrical energy cost for operating an AST.

These technical advances in sludge dewatering technology increase the possibility of burning sludge for a net positive energy gain. However, a suitable boiler is required, since conventional oil or gas burning boilers cannot normally accept solid fuels. Obtaining a permit under air pollution control regulations is often a major technical and/or financial impediment to burning waste sludges.

Activated sludge plants are normally preceded by primary clarifiers, but this is not always necessary in paper mill effluents if suspended solids discharges are controlled by discharge prevention at source.

Design features of efficient AST systems

In recent years the pulp and paper industry has begun to recognize that preferentially promoting non-bulking biological growths and achieving optimal liquid:solids separation in the final clarifier is critical to the success of activated sludge. Many recently installed activated sludge systems include a "selector", an anoxic zone at the inlet to the aeration tank. This improves sludge settleability, with consequent improvements in plant operation and reduction in the sludge bulking problems that inhibit the efficiency of many AST systems.

There should be at least two aerated vessels in parallel for good operation. They can be either 2 metre thick clay (10^{-6} permeability) lined earthen basins or concrete tanks usually about 5 to 7 metres deep. The aeration system must provide adequate dissolved oxygen for all loading conditions. A variety of aeration equipment can be used including fixed low speed turbines and several types of subsurface forced-air diffusers. The selection is dependent on a number of issues including power cost, ease of maintenance, and mixing ability.

The heart of the activated sludge system is the final clarifier. If this unit can consistently separate all the sludge from the effluent and pump it back to the aeration vessel the BOD removal efficiency will be high (above 95% removal). Municipal sewage design criteria for activated sludge treatment are not suitable for design of pulp and paper mill systems. The clarifiers should be fitted with a large sludge centre well to minimize channeling and maximize the consistency of the thickened sludge return. Two final clarifiers in parallel are required for a plant that has to maintain a high level of efficiency and reliability.

The installation should be equipped with a modern process control system, similar to those common in modern pulp and paper mills. All routine, repetitive tasks should be automated as far as possible in the interests of reliability. Sufficient data logging hardware and support software should be installed for prevention and diagnosis of operating problems, and for quality control.

The successful operation of the system is dependent on a thorough understanding of the biological processes taking place, the type of organisms present in the mixed liquor (mixture of biosludge and incoming effluent), the control of the food to microorganism (F:M) ratio, and the control of the sludge age. This normally requires at least one full time professional staff member, support technicians and round-the-clock operators.

Each activated sludge system has its own characteristics, and it is most important that a competent professional manage the system if high BOD and toxicity removal efficiencies are required. The actual performance of treatment systems is just as dependent on the professional, technical and operating resources directed to the operation, as on the details of the design.

The capital and operating cost estimates presented in Chapter 8 assume that the foregoing features would be included in any AST system.

Cold weather operation of AST systems

Until recently there was a lack of reported experience for biological treatment for non-kraft mills operating in cold climates, such as Northern Ontario. There is much to be learned by visiting the recently constructed mills in other Provinces, and examining the effluent data reported to the regulatory authorities. The most relevant experience for Northern Ontario mills is probably to be found in the several mills commissioned over the past few years in Alberta. Some are discussed in Appendix C and effluent data are presented later in this chapter.

For the AST process itself, the principal effect of cold weather is a lowering of the effluent temperature, which can lead to poor BOD and toxicity removal efficiency if the final effluent temperature is below about 20 deg C. This is a serious problem in municipal sewage treatment systems and is the basis for frequent references to poor BOD removal efficiency in winter. In modern mills where the untreated effluent temperature is often high enough to require cooling systems, high performance can be maintained in winter. In some cases, careful design will be required to avoid cold water entering the treatment system. The physical plant has to be constructed to overcome the problems of extreme cold, using the techniques well known to pulp and paper mill operators and the design engineers with experience in cold climates.

The activated sludge process for effluent treatment is very common in Finland and many mills in the US have adopted it. The process is little used in the Canadian paper industry; the only applications are at Thorold (2), Ontario; Whitecourt (2), Alberta; Port Mellon, BC; Hubbards, Nova Scotia and Matane, Quebec, although several more are under construction. Three activated sludge systems operated in Prince George (BC) mills for 10 years and then were replaced or supplemented with an aeration stabilization basin.

Basis for cost estimates in this report

The authors consider that some variation of the activated sludge process is a practical form of biological treatment and have based the cost estimate for non-kraft mills on AST. **This approach should not be considered as a recommendation against the ASB process for these mills.** Selection of AST as the basis for cost estimates was partly due to the difficulty of calculating ASB costs without detailed knowledge of local soils conditions. Most Ontario kraft mills have such studies available, whereas the non-kraft mills do not. The activated sludge process may be more economic than an ASB where a suitable land area is extremely expensive, or so far from the mill that the capital and operating costs of effluent pumping exceed the operating costs for an activated sludge system. Generally, it is more economic to pump effluent several kilometres to an aerated stabilization basin than to install an activated sludge secondary treatment system close to the mill.

5.3.2 Disposal of sludge from high rate biological treatment systems

High rate biological treatment systems, of which the activated sludge process discussed above is by far the most widely used, generally convert a significant proportion of the influent BOD into biomass which has to be removed from the system as a sludge. This is generally known as "secondary sludge" or "biological sludge". Typically in the order of 0.5 dry tonnes of biomass are produced per tonne of BOD removed. It is normally necessary for practical operating reasons to mix the sludge from the primary treatment system with the secondary sludge for dewatering, so the total amount of sludge produced will typically be 2 to 3 times the above figure.

If biological sludge is to be incinerated, then the energy balance will normally be negative, despite considerable expense on polymers and other dewatering aids. The recent improvements in sludge dewatering are claimed to result in a positive energy balance at some mills. However, in some cases, a well dewatered sludge is more indicative of excessive fibre losses in the mill than good dewatering equipment.

If biological sludge is disposed of to landfill, then the water is inclined to leach out, requiring protective measures. The biological sludge is generally useful as fertilizer for agricultural land, where suitable terrain exists, as discussed by Pridham (1990).

For the purposes of cost estimates in this report, it has been assumed that the dewatered biological sludge can be disposed of at a fixed unit cost, without having carried out a detailed analysis of each site, since this was not included in the project mandate. The cost is based on reported experience at several mills, but must be considered approximate since the specific demands of local regulatory authorities must be known to define the costs, and mill staff have indicated considerable difficulty in obtaining such information. Effectively, the only way of determining costs for a new landfill site is to apply for the necessary authorizations and carry out the approval procedure. In some mills, the current cost is very low, since they have landfills that are accepted by the Ministry and any relevant local authorities. When such sites are full, which will occur in from 2 to 20 years at different mills, the cost of land disposal could become very high, but is presently unpredictable. Refer to Table 35 on page 260 for all unit costs. The highest cost that the authors are aware of is a $150/wet tonne tipping fee.

5.3.3 Aerated stabilization basin (ASB)

SUMMARY Aerated stabilization basin (ASB) treatment is a biological process normally applied to primary treated effluents. The principle is based on long-term growth of microorganisms on the soluble materials in the effluent, without the sludge recycle that is characteristic of the activated sludge process. When the microorganisms die, the sludge is used as a substrate for other microorganisms, and thus the organic material causing BOD is digested. The successful operation of an ASB system involves the control of the non-digestible sludge so that low TSS and BOD are achieved in the final effluent without dredging of sludge being necessary. The energy requirements for an ASB system are much less than for an AST system and generation of sludge waste is avoided. However, the lowest attainable concentrations of BOD and TSS in ASB effluent are about the double those for AST.

The aerated stabilization basin (ASB) is a basin in which oxygenation is accomplished by mechanical or diffused aeration units and by induced surface aeration. The turbulence level maintained in the basin insures distribution of oxygen throughout the basin, but is usually (deliberately) insufficient to maintain all the bacterial solids in suspension. Besides providing oxygen, the aerators distribute soluble influent food throughout the basin for biological organisms to metabolize.

The ASB process is currently used at more North American pulp and paper mills than any other form of biological treatment system. A few Southern US mills still use large storage oxidation basins, and discharge effluent only during rainy seasons. There are no such installations of naturally aerated basins in Canada.

The ASB has been almost universally adopted by those kraft mills in the Canadian pulp and paper industry which already have secondary treatment systems. Other processes are likely to be selected for many of the non-kraft mills, including activated sludge using either air or oxygen, and perhaps rotating biological contactors, trickling filters, anaerobic systems and sequencing batch reactors.

Low temperature of the effluent is detrimental to biological treatment system operations, and has to be considered when designing an ASB in most parts of Ontario, particularly where winter conditions are severe. The characteristically long retention of ASB systems makes them more susceptible to cold climates than AST. Most of the currently operating biological treatment systems in Canada are in kraft mills, which have a characteristic foam blanket which lowers heat losses. However, the non-kraft mills will not normally have a stable foam blanket, so that they will be more susceptible to winter weather. The reader is cautioned that there are a number of publications in the literature, usually originating in countries warmer than Canada, which provide procedures for predicting aerated stabilization basin temperatures in winter. If extrapolated to Northern Ontario winter conditions, some will predict erroneously low temperatures for paper industry wastewaters.

ASBs convert some of the entering BOD into biomass, but, in contrast to most other biological treatment systems, are capable of digesting this biomass, so that the net generation of suspended solids is very much lower than for the conventional activated sludge process. This digestion of biomass, known as endogenous digestion, occurs close to the bottom of the basin, and it is essential that the level of mixing and location of the aerators be appropriate for it to take place. A well designed and operated ASB will run indefinitely without the dredging of sludge being necessary, providing the upstream primary treatment system is properly utilized.

The electrical energy required for aeration of an ASB will generally be at least as much as for an AST system for the same effluent. The total electrical power requirement will be much less, since the ASB does not require sludge recycle pumps or sludge dewatering systems.

The ASB process is flexible and does not rely on sludge recycle for successful operation. In some applications the ASB process is considered as an interim step toward an AST system by provision for the addition of clarifiers and recirculating equipment. Because of the long aeration periods employed, conversion of this ASB will usually yield an extended aeration activated sludge system and will require the installation of additional aeration equipment. Care is required in design of any conversion to ensure that the ultimate AST system will perform well, since the retention time of an ASB is normally too long for an AST, but users are often reluctant to abandon the aeration volume, in the mistaken belief that "more is better".

5.3.4 Nutrient addition

Biological treatment systems require carbon, oxygen, phosphorus, nitrogen and other trace materials to function. Sufficient carbon is always available, because normally the objective of the treatment system is to remove the organic carbon compounds from the effluent. Oxygen must be supplied by mechanical devices; most commonly surface aerators. Pulp and paper industry effluents generally do not contain sufficient nitrogen and phosphorus to maintain an optimum microbial population for BOD removal. It is usually necessary to add these nutrients to maintain the efficiency of treatment systems.

Aerated stabilization basins can treat pulp mill effluents successfully without the addition of phosphorus or nitrogen, particularly where retention times substantially exceed five days. In this case, there are some nutrients in the wastewaters, and the discharge of nutrients from ASBs is lower than from high rate biological systems. In general, BOD removal efficiency in paper industry ASBs can be expected to drop by up to several percentage points, if there are no nutrients added to the raw effluent, because growth is limited by nutrients and a decline in the reaction rates in aeration basins. To optimize this trade-off between nutrient and BOD discharges, the needs of the receiving waters have to be considered.

Because nutrients also have a significant impact on the specific microorganisms that predominate in ASB or AST, the lack of sufficient nutrients is widely recognized as being the main factor attributable to AST performance excursions in the industry. Jenkins (1991) has discussed this subject extensively.

High rate biological treatment processes, such as activated sludge, require substantially more nutrients than aerated stabilization basins if they are to approach their potential efficiency in removing BOD. It is frequently stated that BOD and nutrients in the input stream are required in the ratio of 100:5:1 BOD:N:P. However, optimization of pulp and paper effluent treatment systems that operate at high efficiencies has demonstrated that some require less nutrients, approximately 100:3.5:0.6 (Möbius 1991). The actual requirements are site specific, and must be developed by correlating performance and nutrient concentrations in the biological treatment final effluent with nutrient addition rates. Any fixed ratio fails to reflect various sludge ages and predicts equal dosing for all systems regardless of biomass production (Grau 1991). In some mills design weaknesses lead to ineffective practices such as adding orthophosphates to the mill sewers just upstream of the lime mud addition point. In these situations, the lime will precipitate the H_3PO_4 and will remove the phosphorus. It is obviously essential that the nutrients added are actually made available to the microorganisms (Edde 1990). The cost of these chemicals is usually a significant factor in the operating costs of activated sludge plants.

Much of the added nutrient is removed from the system with the waste sludge, but it is generally accepted that 0.5 to 1.5 mg/L phosphorus will be discharged with the effluent, if suspended solids removal in the secondary clarifiers is efficient. The latter implies a suspended solids discharge concentration below 20 mg/L. In an exceptional case, at the Glatfelter mill, one finds phosphorus concentrations consistently below 0.5 mg/L, (refer to Appendix C). However, phosphorus discharges from activated sludge treatment systems can often be much higher, usually due to excessive phosphorus addition or high suspended solids discharges. Kiuru (1990) presented examples of phosphorus discharges frequently over 2 mg/L, and occasionally over 5 mg/L at the mill at Rauma, Finland. The suspended solids discharge from the plant concerned was reported to be from 30 to about 180 mg/L, which is indicative of unsatisfactory operation, although it is a modern installation. Phosphorus discharges up to 20 mg/L have been recorded at the Alberta Newsprint Co. mill (Appendix C).

5.3.5 Control of nitrogen discharges

SUMMARY Ammonia can be transformed into nitrate by Nitrosomonas and Nitrobacter. They have a slow growth rate and thus require a long sludge age to be competitive in the sludge environment. If zones having no aeration are introduced in the biological treatment process, it becomes anoxic, i.e. nitrate is used as an electron donor and is subsequently reduced to atmospheric nitrogen. These processes have become very important in the treatment of municipal effluent. However pulp and paper mill effluents are deficient in nitrogen compounds, and ammonia or urea has to be added, preferably in proportion to the incoming BOD load. Therefore biological nitrification and nitrogen removal may not be of significance for these effluents, although they are inherent in biological phosphorus control.

Concerns over nitrogen compounds in the discharge from pulp and paper industry effluents have primarily involved ammonia toxicity to aquatic organisms (Bennett 1991). Ammonia toxicity has become an issue in recent years although the untreated effluents are invariably deficient in nitrogen. Nitrogen is normally added in the form of ammonia, and at pH values above 8 this could create a problem in the acute toxicity testing with fish. However, under normal operating conditions ammonia toxicity is not a problem in pulp and paper mill effluents, largely because the discharge pH is normally close to neutral[61] (Refer also to page 117).

Today nutrient discharge control by biological organisms has become recognized as perhaps the most practical method of nutrient removal in an effluent treatment system.

Since nitrogen is an essential constituent of microbial cells, any net growth of biomass that is removed from the waste stream will cause some nitrogen removal. The amount of nitrogen that can be removed by this mechanism is limited by the amount of net growth, which in turn depends on the carbonaceous organic content of the wastewater and the system's operating conditions. The nitrogen content of microbial cells is approximately 12.5% by weight.

Nitrification is the biological oxidation of ammonia to nitrate, with nitrite formation as an intermediate. The microorganisms involved are the autotrophic species *Nitrosomonas* and *Nitrobacter*, which carry out the reaction in two steps:

$$2NH_4^+ + 3\,O_2 \xrightarrow{\text{Nitrosomonas}} 2NO_2^- + 2H_2O + 4H^+ + \text{new cells}$$

$$2NO_2^- + O_2 \xrightarrow{\text{Nitrobacter}} 2NO_3^- + \text{new cells}$$

It is generally accepted that the specific growth rate of *Nitrobacter* is higher than the growth rate of *Nitrosomonas* and hence there is no accumulation of nitrite in the process and the growth rate of *Nitrosomonas* will control the overall reaction.

The empirical overall reaction including oxidation and synthesis is:

$$NH_4^+ + 1.83\,O_2 + 1.98\,HCO_3^- \longrightarrow 0.98\,NO_3^- + 0.021\,C_5H_7NO_2 + 1.88\,H_2CO_3 + 1.04\,H_2O$$

Thus, the stoichiometric equation for nitrification indicates that for one gram of ammonia nitrogen removed (USEPA 1975):

4.2 g of O_2 are consumed
7.1 g of alkalinity (as $CaCO_3$) are destroyed
0.17 g of new cells are formed
0.08 g of inorganic carbon are consumed.

These data indicate the additional oxygenation capacity required to achieve nitrification.

For effective nitrification to occur there must be a rather long sludge age, 20 days or longer is not an uncommon sludge age for efficient nitrification treatment plants. Short sludge ages will result in a washout of these organisms. Nitrification occurs over a temperature range of 5 to 45 deg C with the optimum range being 25 to 35 deg C. Nitrification is a zero order reaction down to very low concentrations in the order of 1.0 mg/L. Since nitric acid is produced in the oxidation process it is necessary to provide 7 mg/L alkalinity per mg/L ammonia oxidized. The rate of nitrification has been shown to be dependent on the dissolved oxygen at concentrations less than 2 mg/L. Low temperature applications (10 deg C) of combined carbon oxidation-nitrification in completely mixed activated sludge systems require very long hydraulic residence times to achieve favourable conditions for virtually complete nitrification. As temperatures rise, required retention times are reduced. At 20 deg C, less than five hours is required for virtually complete nitrification. The USEPA recommends a safety factor in the order of 2.5 (USEPA 1975) which is included in the critical sludge age calculated above for design purposes to ensure that ammonia breakthrough does not occur during daily peaks in loads. The required sludge age can be achieved by varying either the MLVSS or the hydraulic detention time.

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[61] ***The authors have heard of effluents containing residual nitrogen becoming acutely lethal during storage or shipping prior to toxicity testing, due to ammonia formation.***

In some ecosystems, particularly brackish or marine ones, algae may also be limited in nitrogen salts, ammonia and nitrate. Therefore, nitrate discharges are becoming of increasing importance for many treatment plant effluent discharges worldwide. Elimination of nitrate by biological denitrification is achieved under anoxic (absence of molecular oxygen) conditions by heterotropic microorganisms that utilize nitrate as a hydrogen acceptor when an organic energy source is available. Denitrification will also occur under conditions of endogenous respiration, although at a much slower rate:

$$2(NO_3)^- + \text{substrate} \longrightarrow N_2 + CO_2 + H_2O + OH^- + \text{cells}$$

Nitrate nitrogen is converted to reduced forms such as N_2, N_2O and NO. The breakdown of carbonaceous organics in the denitrification reactions is similar to that in the aerobic process. Thermodynamic data show a higher energy yield from the aerobic metabolism of organic carbon compared to anoxic denitrification. A factor that indicates the need for strict anoxic conditions in a denitrifying system. Many activated sludge systems are operated so that aerobic processes and denitrification can occur simultaneously due to the presence of a dissolved oxygen gradient across bacterial flocs.

The simplest configuration enables carbonaceous oxidation, nitrification and denitrification to occur in a single basin. This can be accomplished by careful positioning of the aeration equipment to maintain defined aerobic-anoxic zones in different basin sections. A simpler system utilizes a single basin for both aeration and sedimentation by providing intermittent aeration to create aerobic and anoxic time sequences. No matter what system is used, it is necessary to provide a sufficiently long solids retention time to ensure the growth of nitrifying organisms; a sufficient active fraction of biomass at a dissolved oxygen level adequate for nitrification to occur, and an anaerobic or anoxic phase of sufficient duration to permit nitrate reduction (Eckenfelder 1989).

Despite the concerns expressed about ammonia toxicity in effluent from mills discharging strong wastes, several mills routinely pass the acute lethality tests, including Alberta Newsprint.

Presently there is a lack of ammonia data for effluents from ASB treatment systems in the pulp and paper industry, so it is not possible to evaluate their performance in achieving nitrification. Several mills, including Weldwood at Hinton (Andrews 1991), E.B. Eddy at Espanola (MISA 1991) routinely pass the LC_{50} test with zero mortality. The authors are not aware of any mills reporting ammonia toxicity.

5.3.6 Control of phosphorus discharges

SUMMARY Phosphorus is a limiting nutrient for microbiological growth in biological treatment of pulp and paper mill effluent, and its control thus involves an accurate assessment of the need for adding it, normally in the order of 0.6 to 1:100 as the ratio of P:BOD. Long retention ASB systems often operate without addition of phosphorus. The quantities of phosphorus which have to be added to an AST can be limited by applying biological phosphorus control.

Concern over phosphorus discharges is related to the fact that algae growth in most fresh water ecosystems is phosphorus limited. Excessive concentrations of phosphorus may result in a eutrophied ecosystem, oxygen depletions and fish kill.

Control of phosphorus emissions may require a trade-off between attaining low BOD discharges and low phosphorus discharges. Part of the problem is that sufficient nutrient residual must exist in the wastewater **at all times** during the treatment process. Thus nutrient addition rates must be paced with BOD removals achieved. Whereas an effluent treatment plant treating a uniform BOD load may achieve a final effluent concentration as low as 0.2 mg/L, the same plant under varying load conditions will require a higher phosphorus concentration in the final effluent to assure the system is not operating in a nutrient limiting condition. The proper selection of analytical procedures for phosphorus is critical (Refer to page 118).

Pulp and paper mill effluents are typically deficient in phosphorus relative to the quantities required for the operation of most biological treatment systems. Therefore phosphorus must often be added in adequate amounts to avoid phosphorus limited growth and a decline in reaction rates in aeration basins. Phosphorus deficiency is a selective factor, frequently leading to the deterioration of sludge settleability and slow biodegradation of carbonaceous compounds (Eckenfelder 1985, Vuoriranta 1989). However, in some cases pulp mills discharge sufficient quantities of phosphorus with the untreated wastes. The Hinton mill discussed in Appendix C achieves very low BOD and TSS discharges, so is presumably not phosphorus deficient. There was no phosphorus addition during the period reported in Appendix C, yet the discharge in the treated effluent was relatively high, implying that the untreated effluent was NOT deficient in phosphorus.

In biological treatment plants handling pulp and paper mill effluents, the first step in phosphorus control is to define the criteria for adequate phosphorus feed. The minimal nutrient requirements for AST are in the range of 0.6 to 1:100 phosphorus:BOD ratio to assure phosphorus limited growth does not occur while still achieving optimal BOD removal during biotreatment (Edde 1968, Möbius 1991). Discharges of phosphorus have in the past been considered a secondary problem to BOD removal and TSS control. This attitude is changing rapidly. Wastewater discharges to the Great Lakes Basin are generally required to limit their discharges of total phosphorus to 1 mg/L or less under an agreement between the United States and Canada (Reid 1991, Great Lakes 1987). Regions where effluent phosphorus concentrations of 2 mg/L or less are required are summarized in Table 22. All these values are considered attainable by the relevant regulatory authority.

Table 22 Examples of effluent phosphorus standards

Region	P standard (mg/L)
USA	
Great Lakes	1.0 (if > 2640 m^3 per day)
Florida	1.0 (for lake, bay, impoundment or estuary discharges)
Chesapeake Bay Basin*	
Pennsylvania (lower Susquehanna)	2.0
Maryland	0.2, 1.0, 2.0
Virginia (lower Potomac River)	0.2, 0.4, 0.5, 1.0
Washington, D.C.	0.23
Reno Sparks, Nevada	0.5
Lake Tahoe, California	1.0
Switzerland	1.0 or 85% removal for discharges to lakes
Sweden	$\leq$ 1.0

* Varies according to stretch of river. Above is a simplified representation of regulations which are sometimes complex, with local variations.

Chemical phosphorus removal

Phosphorus can be precipitated by the addition of coagulants such as aluminium, ferric or calcium salts or polyelectrolytes. They can be added in the secondary clarifier, but it is more common to have an add-on chemical treatment unit. This is primarily used when phosphorus discharge criteria are lower than can be achieved in a secondary biological effluent treatment plant. This is known as tertiary treatment which is discussed in more detail on page 220.

5.3.7 Maintaining the nutrient allowance

In a multi-cell ASB with nutrient addition, it is possible that a phosphorus concentration shortfall will exist immediately at the head end of the ASB where there is normally high biological activity, high mixing energy and high phosphorus demand. The high mixing energy prevents deposition of biological organisms which are therefore displaced from the head end of the ASB. The nutrient demand at the head end of the effluent treatment system may deplete the available phosphorus in the wastewater. Between the head end and midsection of the ASB there may be a portion of the ASB where phosphorus concentrations are not adequate to meet nutrient demands and a growth limiting condition develops.

After this midsection growth limiting condition, due to a lack of nutrients, the wastewater will pass into a section of the treatment system where recovery of nutrients released from decomposing sludge at the bottom of subsequent aeration basin cells again makes available adequate nutrients. This will occur toward the end section of the ASB where adequate nutrients resulting from resolublization of biological organisms are recovered by the microorganisms.

The midsection nutrient deficiency may not be noticed if only the final effluent phosphorus concentration is monitored. A nutrient shortfall was observed at the midsection when monitoring throughout the ASB basin at Proctor and Gamble, Grande Prairie, Alberta. A similar problem was discovered and corrected several years ago at a Washington State ASB. A similar nutrient shortfall situation can also exist with "contact stabilization" or other modifications to AST, and avoiding it is essential for attaining optimum effluent quality. This is one example which demonstrates the need for competent technical supervision of aerated stabilisation basins or ASB if efficient treatment is to be attained.

Continuous BOD monitoring for nutrient addition control

Since a BOD test requires five days to be completed, it is not possible to simply control phosphorus and nitrogen addition in direct proportion to incoming BOD.

Mechanical and sulphite mills can estimate BOD discharges quite accurately from the production rate of the refiners/grinders/digesters, since BOD is directly proportional to those. At least one mill with high strength BOD, the Millar-Western bleached CTMP mill at Whitecourt, Alberta does so successfully (Personal contact). For kraft mills (and any other mill with a chemical recovery system) this approach, in principle, can also be used, but with so many variables the prospects for success are poor.

Continuous short term BOD measuring instruments are becoming available (Arthur 1986, STIP 1991). The authors do not consider them as alternatives to the classic BOD test, but rather as useful tools to assist operators in controlling nutrient additions to plants with variable effluent loadings. One example is the Biox 1000 a commercially available sensor from STIP for continuous short term BOD measurements. The sensor measures an initial rate of oxygen consumption which correlates to the BOD_5 figure for a given effluent. For control of nutrient addition the initial rate of oxygen consumption is a better control variable than BOD_5 (because there is no AST with 5 days retention time). It's analysis time is three minutes and it can measure from very low values to several thousand mg/L BOD_5. It could be calibrated to show COD or nitrification rates for a given effluent as well.

The instrument one author saw at the Feldmuehle mill in Flensborg was computerized with automated daily cleaning and calibration programs, and warning to a central computer of errors etc., thus minimizing operator attention. Equipment of this type has been used in Germany for approximately 5 years with more than 200 installations today, according to information obtained from the vendors. They have identified 8 installations in the German paper industry, two of which are used for process control of activated sludge, and 6 installations for inlet or outlet BOD monitoring.

Nutrients in Ontario mill effluents having biological treatment

Nutrient discharges from seven pulp and paper mills in Ontario which operate biological treatment systems are shown in Table 23.

These data indicate final effluent phosphorus concentrations below 1 mg/L occur at all effluent treatment plants except for highly loaded ASBs and the one anaerobic plant. The authors consider that the technology exists to maintain adequate nutrients in the treatment system while maintaining a final effluent concentration of phosphorus below 1 mg/L.

When mills discharge effluents with high nutrient concentrations after secondary treatment, one option to achieve less than 1 mg/L phosphorus concentration in the final effluent is tertiary chemical assisted coagulation (CAC).

This may be necessary if mill effluents contain high BOD concentrations making it difficult to both assure adequate phosphorus in the wastewater being treated and to maintain a less than 1 mg/L phosphorus concentration in the final treated effluent. Alternatively, where receiving water dissolved oxygen is high, but nutrients are particularly undesirable, the best technology would be to operate the effluent treatment plant for minimum phosphorus discharge instead of minimum BOD, as is the more common practice. Refer to page 118 for a discussion of phosphorus analysis.

Table 23 Pulp and paper mill biological treatment plants in Ontario

Mill and location	Operation description	Tot-P*	Tot-N	NH_3/NH_4	NO_3
Boise (Fort Frances)	Highly loaded ASB	2	13.2	0.27	0.03
CPFP (Dryden)	Highly loaded ASB	2	3.3	2.3	0.3
Eddy (Espanola)	Efficient ASB	0.6	5.6	1.2	0.02
K-C (Terrance Bay)	Efficient ASB	0.5	6	1.4	0.1
Strathcona, Napanee	ASB, lightly loaded	0.6	12	1.39	0.04
Q & O, Thorold	Oxygen AST	0.5	3.75	1.45	0.47
MacMillan, Sturgeon F.	Anaerobic, with NO aerobic	1 to 2.5	50	27	630

Data are shown as mg/L

*Source: MISA Monitoring Program (1991).

Nutrient addition contrast

Two recently constructed pulp mills in Whitecourt, Alberta provide contrasting experiences in optimal phosphorus additions to mill wastewaters treated in activated sludge systems. Millar Western Pulp started up a 220,000 tonnes per year alkaline-peroxide pulp mill in 1988 initially with an ASB wastewater treatment that was subsequentially converted to extended aeration activated sludge. The Alberta Newsprint Co. started up in September, 1990 (Refer to Appendix C for a description). Neither mill has final effluent discharge limitations for phosphorus.

The Alberta Newsprint Co. effluent is treated in an AST with six day total retention time (the AST reactor has 2.5 days retention, the remainder in a polishing pond and equalization basin) and 10 to 15 day sludge age. The biological treatment performance was optimized for BOD at the expense of high phosphorus concentrations in the treated effluent. The wastewater influent BOD was approximately 1,200 mg/L, and an excess of nutrients was added such that final effluent phosphorus during initial operation was in the range of 18 to 20 mg/L. More recent operation has brought this downward to about 5 mg/L.

Millar Western Pulp operates an AST system with 10 day sludge age and approximately 3,000 mg/L BOD in the influent. The operators have attempted to minimize nutrient addition. To accomplish this they pace nutrient feed to the metering screws that feed the refiners in the pulp production process (effectively using pulp production rate as an indicator of the BOD load entering the treatment system). Phosphorus concentration in the treated effluent is less than 1 mg/L average, despite the need for approximately 200 mg/L phosphorus in the influent.

This experience suggests that a dedicated effort by ingenious mill operating personnel can result in minimal nutrient discharges to the environment. Few mill processes lend themselves to this elegantly simple way of "measuring" BOD constantly, but the concept could be developed in some others, particularly in mechanical pulp mills.

5.3.8 AOX removal by biological treatment

Biological effluent treatment systems are generally designed to remove BOD and acute toxicity, but incidentally reduce the quantities of many substances in the wastewaters, including AOX.

The AOX removal performance of a number of different external treatment systems that has been evaluated. Wilson (1991) concluded that the conventional biological treatment systems are the best demonstrated mill scale external effluent treatment technology available. The most commonly used system in kraft mills is the Aeration Stabilization Basin (ASB) while there has been increased interest in the Activated Sludge Treatment (AST) system. There is a wide variation in AOX removal efficiency reported in the literature for both types of treatment systems. Wilson reported 16% to 68% for ASBs and 14% to 65% for AST systems.

The AOX parameter measures a number of chemical compounds that have varying degrees of stability. Samples stored in the refrigerator will dechlorinate 10 to 20% within one or two weeks. AOX from the chlorination stage is sensitive to solution pH and will dechlorinate when exposed to a high pH and sulphide i.e. black liquor. The results reported in the literature includes laboratory systems as well as mill scale systems. High AOX reductions are usually associated with laboratory results. Little information is given on what the untreated sample represents, or how it was handled prior to treatment. Since the handling of the samples appears to have a major impact on treatment results, the authors have used literature reports with caution. The wide variation in reported results may be the result of the "Crofton" effect discussed on page 216.

For predicting the characteristics of the effluents from the various BAT Technology Trains in this report an AOX removal efficiency of 40% has been taken as the base for the ASB treatment. This is supported by Wilson (1991) and by Vuoriranta (1989). For the AST systems, a removal efficiency of 35% has been used as a base. This is supported by the above references and by Rempel (1991). No difference in performance between air and oxygen AST systems has been allowed. This is supported by Rempel (1991). The authors are aware of several ASB and AST systems which have not been reported in the literature, whose performance confirms the foregoing values.

The value used for the ASB is higher than the 32% indicated in the widely quoted study by Gergov. However, his conclusions were based on an ASB which removed only 49% of the incoming BOD, whereas ASBs in Ontario are substantially more effective[62] in removing BOD.

AOX removal may well be in the order of 40%, but there will be a major difference in the environmental impact of the discharged AOX depending on its origin. The DOC/AOX or COD/AOX ratio may give an indication of the extent of chlorination of the organic matter. If this figure is low the material is highly chlorinated. Refer to Appendix C (Mönsterås) for other discussion on the specific removals. Refer also to page 123.

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[62] *An ASB operating with a BOD removal efficiency of only 50% is either in serious trouble, or is designed to unusual standards, presumably because of unusually high permitted discharge rates.*

5.3.9 Removal of metals in biological treatment

Metals cannot be destroyed, only redistributed in the environment. Biological treatment systems inevitably remove some proportion of metals from the effluent stream being treated. Analysis of whether this is environmentally desirable or not is beyond the scope of the present report. Generally, activated sludge systems will remove over half the metals in an effluent stream, concentrating them in the waste sludge. Chemically assisted coagulation will remove some proportion of the metals, also concentrating them in the waste sludge. Aerated stabilization basins have less effect.

The authors found few data in the literature on removal of metals from pulp and paper industry effluents, presumably because metals are not generally considered as a major environmental problem in this field. There is, however, an extensive body of literature and experience in removals of metals from domestic wastewaters and metal processing industries. The concentrations of metals of interest in the latter are generally much higher than those found in pulp and paper mill effluents, but many municipal effluents contain comparable concentrations of metals to those found in the Ontario mills during the 1990 monitoring program.

Metals removals in activated sludge treatment systems

Many authors have reported on the ability of activated sludge treatment systems to remove metals from domestic wastewaters. Data from the following references were reviewed: Aulenbach 1985., Brisbin 1984, Esmond 1974, Flynn 1979, Govinda 1985, Keinath 1984, Lue-Hing 1980, Michalczk 1979, Neiheisel 1988, Oliver 1975, Petrasek 1983, Reen 1974, Robinson 1980, SCS 1984, Steeves 1982, Stonerook 1984, USEPA, 1982, and Woodiwiss 1979. Information on full scale operations with influent metals concentrations in the ranges shown in Table 18 on page 138 was extracted to develop Table 24.

Table 24 Metal removal efficiencies expected in activated sludge treatment systems

Metal	Removal % Minimum	Removal % Average	Comments (for concentrations in Ontario mill effluents)
Aluminum	55	85	Minimum removal 80% for influent >2mg/L
Cadmium	30	70	Minimum removal 60% for influent >10 μg/L
Chromium	50	75	Removals independent of influent concentrations
Cobalt	10	40	Data very scattered
Copper	50	70	Removal efficiency rises somewhat with influent concentration
Molybdenum	5	10	Very few data available
Nickel	10	40	Data very scattered, removal independent of influent concentration
Thallium	?	75	Few data available
Vanadium	1	30	Data very scattered
Mercury			Insufficient data for the low concentrations found in MISA
Zinc	20	70	Minimum removal 40% for effluents greater than 200 μg/L

Removal efficiencies indicated are based primarily on reported operating experience in full scale activated sludge systems treating municipal wastewaters with some industrial components.

All the metals removed from the wastewater streams are retained in the waste activated sludge, and will accumulate at the final disposal point. If the sludge is incinerated, most of the metals will remain with the ash, and some proportion will be discharged to atmosphere.

Metals removal in aerated stabilization basins

There are few published reports of metals removal in aerated stabilization basins. In principle, one would expect very little, since the ASB is designed to digest most of the sludge formed, and allow the remainder to discharge with the effluent. The ASB is effective in mineralizing biodegradable organics, and also degrades some substances which could be considered as non-biodegradable in the time scale involved in an activated sludge system. However, the metals, being elements, can never biodegrade.

The references listed above for the activated sludge systems include very few data on aerated stabilization basin performance. All indicate removal of metals occurring, but the authors did not consider the data adequate to draw conclusions. Removals indicated were generally about half those indicated in Table 24 for the AST process.

5.3.10 Theory vs practice in biological treatment

The actual performance of biological treatment systems frequently falls short of expectations based on theory or the somewhat idealized world of textbooks. Reasons for this range from sloppy operation to real technical difficulties that have not yet been completely resolved, despite about 100 years experience in building and operating such systems. One purpose of this report is to assess the technological and economic feasibility of achieving various levels of effluent quality.

The technically sound reasons for differences between practical performance and expectations based on research and pilot plants include:

Pilot scale biological treatment systems operate in vessels with a much higher wall:volume ratio than the full size operations. This allows the development of more effective biomass growth. The problem is, of course, worse in very small bench scale trials than where the pilot operation uses tanks with capacities of hundreds of litres.

Many pilot studies are sheltered from real life variations in raw effluent quality, so that some particular aspect of the operation can be studied. In the authors' experience, a high proportion of reports on pilot biological treatment trials underestimate the significance of this, or where the report is realistic, the readers seem not to notice. Pilot systems are rarely exposed to all the meteorological variations experienced by a full scale system. This is particularly important in low-rate systems.

It is the authors' opinion that bench and pilot plant studies should be conducted under mill environment conditions including feed conditions that are representative of the concentration and flow variation of mill effluent. The feed system for many lab and pilot plant activated sludge systems is unintentionally equivalent to an anoxic or anaerobic zone discussed previously and hence the experimental results do not correlate with "real life" conditions. The net result is that the pilot plant exhibits substantially better performance than does the full scale installation.

A major, correctable cause of differences between pilot and full scale operation is that greater technical resources are often directed toward the pilot systems. It cannot be over emphasized that in all the mills that the writers are aware of with **excellent performance of their biological treatment systems, considerable technical and personnel resources are committed to their operation**. Typical examples would include one or more full time professionals, and several laboratory technicians, in addition to trained shift operators, and qualified maintenance personnel. The professionals would be in frequent contact with other operations, and would have ready access to technical conferences and specialized consultants. The estimates of the operating costs in Chapter 8 reflect this.

5.3.11 Attainable quality for biological treatment systems

Virtually all monitoring of pulp and paper industry effluents in North America, including the 1990 MISA monitoring program, is based on a series of samples, each one of which represents the average of 24 hours discharge. All comments in this report should be understood in this context.

Effluent quality is often defined in terms of average values recorded for a calendar month and maximum daily values. When evaluating best treatment plant performances there is scientific basis to use 30 days rolling average (AVG_{30}), but most regulatory authorities in North America, evaluate compliance on the basis of the calendar month, for administrative convenience. To evaluate the data presented in this report on operating effluent treatment systems, the authors calculated a 30-day moving average wherever possible, since this provides a better picture of the operation when data is available for a few months only. In practice, the worst average over a calendar month will be less that the worst 30-day moving average, except in the rare event where the two coincide. The graphs of 30-day moving average discharge concentrations in this report demonstrate that the practical difference will be minor.

There is also a scientific basis for defining the maximum daily value on a statistical basis that uses a specified percentile of the annual data. The annual 95 percentile (MAX_{95}) is frequently used (Möbius 1991), meaning that the daily figure would be below MAX_{95} at least 340 days per year. Regulators of course prefer to work with a simple daily maximum value, since it is administratively simple, and virtually all North American regulatory agencies have adopted this approach.

The authors calculated the annual 95 percentile average (AVG_{95}) to evaluate the long-term performance of some treatment plants. For practical purposes, this value will be almost equal to the long-term average, unless there are few data and several extreme values. This value can, of course, not be complied with on a rolling 30 days average or calendar month basis.

The MISA approach (MISA/IRC 1990) considers two forms of Long Term Averages. One is calculated after outliers have been rejected from the available data, while the other considers all available data. The latter is being most generally used, and has been adopted in this report. The practical difference is small where many data are available, as is the case for substances listed in Table 25.

Calendar month averages have been used when lack of data prevented calculations of 30 day rolling averages. Daily maximum values will be referred to as within the 95 percentile (MAX_{95}). **Reference to attainable effluent qualities in this report cannot be made without specifying**

their basis, AVG_{30} (30 day rolling average), AVG_{95} (yearly 95 percentile average), MAX_{95} (yearly 95 percentile maximum)or LTA (Long term average).

Table 25 presents the discharge concentrations for traditional pollutants that the authors consider attainable with biological treatment systems, treating pulp and paper industry wastes in Ontario conditions.

Table 25 Attainable concentrations for TSS, BOD, P and N in ASB and AST treatment

	Aerated stabilization basin				**Activated sludge treatment**			
	LTA	AVG_{95}	AVG_{30}	MAX_{95}	LTA	AVG_{95}	AVG_{30}	MAX_{95}
TSS	46	45	55	70	21	20	30	40
BOD	21	20	30	50	11	10	15	25
Total Phosphorus	0.8	0.8	1.0	1.5	0.8	0.8	1.0	2.0
Total Kjeldahl Nitrogen	9	9	10	18	10	10	12	20
NH_3-Nitrogen	1.7	1.5	2.0	4.5	0.9	0.8	2.0	6.0
NO_3-Nitrogen	0.7	0.5	1.2	2.0	0.7	0.5	0.8	1.0

Data are shown as mg/L. The presentation of this table in mg/L does not imply that the authors consider regulations should be expressed in mg/L. These concentrations are only intermediate values for calculations to arrive at actual loads in kg/tonne[63]. LTA (Long term average)
AVG_{30} (30 days rolling average) AVG_{95} (Annual 95th percentile average) MAX_{95} (Maximum day, 95th percentile)

The above table is a compromise between BOD/TSS performance and allowable nutrient discharges. Korsnäs and Mönsterås are two Swedish bleached kraft mills that both have aerated stabilization basins (ASB). The following figures, in Table 26, illustrate this compromise in the fact that Mönsterås has the better TSS/BOD performance, but Korsnäs has the better Tot-P/Tot-N performance. However, neither of these mills have exemplary ASB performances.

Table 26 ASB Performance at Mönsterås and Korsnäs

	Mönsterås	**Korsnäs**
BOD_7	31	78
Tot-P	2.5	0.35
Tot-N	9	4.3

The data are shown as mg/L, Long term average.

The following discussion summarizes the rationale behind the figures presented in Table 25.

Long term operating data were studied for the mills presented in Appendix C. Also, data and operating problems from the authors experience over the past 20 years within the North American and European industry and with regulatory agencies were considered. Table 27 shows data for a number of the better treatment plants identified. Two of these mills are more than 50 years old and have treatment plants built in the 1950s with various modifications since their installation. One is a greenfield mill started up in 1990 (ANC). This mill is not subject to any nutrient control regulation. The plots of AVG_{30} for the parameters in discussion are shown in Appendix C.

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[63] *Hylta, Sweden (Appendix C) discharges BOD 76 mg/L, TSS 53 mg/L, Tot-P 0.7 mg/L and Tot-N 3.6 mg/L as an annual average. However their water consumption is only 12 m^3/tonne, so the effective loadings are very low.*

The AVG$_{95}$ performance quite logically shows lower numbers than the AVG$_{30}$. In extreme situations the AVG$_{30}$ may even exceed the MAX$_{30}$, because the extreme peaks are excluded from the latter.

Table 27 Effluent discharge concentrations for selected mills

Mill name Treatment plant	K-C Terr. B ASB	Eddy Espanola ASB	Hinton ASB	ANC AST	Canton AST	Glatfelter AST
TSS						
MAX$_{95}$	62	46	62	30	40	36
AVG$_{30}$	55	41	43	31	36	30
AVG$_{95}$	42	24	34	12	21	21
Long Term Average	43	25	38	12	22	21
Maximum recorded	76	66	78	107	164	50
BOD						
MAX$_{95}$	30	32	33	20	19	16
AVG$_{30}$	30	26	29	12	15	15
AVG$_{95}$	15	16	25	8	12	9
Long Term Average	16	17	24	8	11	9
Maximum recorded	43	120	41	34	31	60
Phosphorus						
MAX$_{95}$	0.60	0.65	2.48	14.10		0.23
AVG$_{30}$	0.60	0.75	1.88	13		0.22
AVG$_{95}$	0.50	0.50	0.99	7.2		0.18
Long Term Average	0.5	0.5	0.8	9		0.23
Maximum recorded	0.6	0.75	3	19		0.25
$NH_3 + NH_4^+$ - N						
MAX$_{95}$	1.80	1.08	4.40		2.77	1.75
AVG$_{30}$	1.5	1.25	4.10		1.83	1.28
AVG$_{95}$	0.74	0.90	2.98		1.60	0.56
Maximum recorded	1.5	1.25	5		4.7	2

All data were calculated by authors from operating reports, and are expressed in mg/L.
Refer to Appendix C for descriptions of mills and sources of data

Total Suspended Solids

Biological treatment results in loss of some bio-solids mass (TSS) in the final treated effluent. Generally AST is capable of realizing a lower secondary effluent TSS than is possible with ASB treatment. This is because AST exhibits natural flocculating properties whereas ASB system effluents exhibit disperse growth biocell TSS which is difficult to settle. Excellent activated sludge final effluent TSS is often about 20 mg/L AVG$_{95}$, 30 mg/L AVG$_{30}$ and 40 mg/L MAX$_{95}$. This is achieved by the ANC and Canton mills. Excellent ASB final effluent TSS may be expected to be less than 45 mg/L AVG$_{95}$, 55 mg/L AVG$_{30}$ and 70 mg/L MAX$_{95}$. However, a mill such as Kimberly-Clark (Terrace Bay) has excellent performance for BOD (15 mg/L AVG$_{95}$) whereas the TSS is around 45 mg/L AVG$_{95}$.

BOD

Low BOD values are often associated with high levels of nutrients, but as shown in Appendix C, this is not so for the Glatfelter mill. ANC and Canton both demonstrate performance superior to the 15 mg/L AVG_{30} and 25 mg/L MAX_{95} figure given in Table 25. ASB cannot achieve the same level of BOD for the reasons discussed on page 212. However, Kimberly-Clark (Terrace Bay), Weldwood (Hinton), and E.B. Eddy (Espanola) show performances superior to the 30 mg/L AVG_{95} and 50 mg/L MAX_{95} figures shown in the table.

Phosphorus

Several of the mills discussed in Appendix C have demonstrated their ability to maintain 30 day rolling average phosphorus discharges below 1 mg/L.

For mills with activated sludge treatment systems, Hylta discharges 1.1 mg/L, annual average, but with the exceptionally low effluent flow of 12 m^3/tonne newsprint produced, the phosphorus loading is quite low. Alberta Newsprint phosphorus discharges are much higher, although its effluent complies with local requirements in all respects. Personal contact with the mill staff indicated that their philosophy at start-up was to ensure sufficient nutrients for efficient BOD removal and minimal TSS discharges. More recently measures to reduce phosphorus discharges have been initiated. The data in Appendix C demonstrate a steady reduction in phosphorus discharges.

The Glatfelter mill provides an extreme example. It has one of the oldest activated sludge installations in the pulp and paper industry in North America. The mill's biological treatment system has consistently been considered the "Best of the Best" by NCASI and EPA during the past twenty years, e.g: P discharge of 0.1 mg/L. The plant has been well known for many years as having an exceptionally competent operating team, with strong management support. The company was picked as the "best managed paper company in the US" because of its ability to keep its operations well tuned to success over a significant span of time (Cox 1991). Cox was apparently referring to the company's 125 year financial and labour relations record, but also mentioned their successful environmental program. The mill is located on a small receiving water, and has been under strong environmental pressure for at least 30 years. Their data has on many occasions undergone scrutiny by the USEPA, Pennsylvania DNR and NCASI. Glatfelter's effluent data performance has stood the test of time for more than two decades; more scrutiny than any other mill in North America. The authors do not consider such a low phosphorus discharge to be BAT, since they were unable to find any other plant which has reproduced the performance. However, this example does demonstrate that the potential exists for further improvements in phosphorus discharges for AST systems.

The ASBs at the Terrace Bay and Espanola kraft mills discharge less than 1 mg/L most of the time, and the annual average for Korsnäs is as low as 0.35 mg/L (with probably a BOD tradeoff). Therefore slightly lower Tot-P figures can be obtained for ASB systems.

Review of the foregoing data, and experience elsewhere, led the authors to conclude that the phosphorus discharges shown in Table 25 are attainable, assuming adequate design and diligent operation. The 1 mg/L AVG_{30} and 2 mg/L MAX_{95} figure for AST is supported by European pulp and paper mill treatment plant experience (Möbius 1991). ASBs frequently have lower discharges of nutrients.

Nitrogen

Good process control for ammonia N leads to concentrations around 1 mg/L. However, due to fluctuations in the influent BOD, spikes of ammonia up to 10 mg/L may be unavoidable (Möbius 1991). The only way to effectively reduce this figure is to add nutrients as a function of the BOD load. The BOD load can be assessed in a number of ways, but some form of on-line determination is necessary to achieve effective control of nitrogen discharges. In the example given on page 208, the BOD load was assessed indirectly from the pulp production. Instruments are now becoming available to estimate BOD loads on-line, as discussed on page 207.

It follows that ammonia N can be controlled to an AVG_{30} of 2 mg/L and a MAX_{95} of 6 mg/L for AST. A sludge that is short of nitrogen nutrients has poor settling abilities and can cause poor performance of the treatment plant. Again an ASB should perform slightly better in terms of ammonia. There is a tradeoff between low BOD/TSS and low ammonia/ammonium/phosphate in that a high influent BOD/TSS load, often exceeding 1000 mg/L, can only be treated efficiently in an AST system after adding substantial quantities of ammonia and phosphate.

Nitrate is not a problem in pulp and paper mill effluents. Hinton reports values well below 0.5 mg/L for an ASB (Appendix C). An AST with an anoxic selector stage will eliminate any nitrates that may have been formed by nitrification of ammonia. The attainable values presented in Table 25 are lower than the present USEPA drinking water criteria of 10 mg/L NO_3.

Extremely low discharges for Total-N are unattainable (and probably unnecessary), because there may be a certain percentage of the influent nitrogen that is persistent, in the order of 7% (Grau 1991). Sludge that is starved in nitrogen tends to form filamentous sludge with poor settling abilities. Activated sludge plants for municipal sewage in Denmark generally have performed better than 8 mg/L. Mönsterås reported 9 mg/L as an annual average for an ASB, but Korsnäs was better 4.3 mg/L. Faced with the chance of having a fair amount of persistent nitrogen and the consequences of having a nitrogen starved sludge the Tot-N attainable level is probably not lower than 10 mg/L for AVG_{95} and 20 mg/L for MAX_{95}. The lower figure for ASB reflects the lower ammonia level.

5.4 Tertiary Treatment

5.4.1 Crofton caustic treatment process for AOX removal

This process could be considered to be "in-plant", but since it consumes chemicals and does not involve any recovery of useful material, it is considered by the present authors as an external, physical-chemical effluent treatment system for selected streams.

A caustic treatment process involving neutralization of bleach plant effluent with lime mud and alkaline sulphide process liquor has been developed at the Fletcher Challenge Inc. mill in Crofton, BC. The pH, reaction time, and temperature are controlling parameters. AOX reductions of 60 to 70% are reported to be attainable by this method prior to effluent treatment. The treatment and experience leading to the method are detailed by Milosevich and Hill (1991).

This process is an example of how technology is frequently developed in the pulp and paper industry, as outlined in the discussion on science vs technology in this report. The mill staff observed some unexplained occurrences when carrying out pilot plant trials intended to assist in the design of a secondary treatment system. Their investigative program lead them to the caustic treatment process. The results have been confirmed by PAPRICAN and by another mill.

The organochlorines are apparently dechlorinated, so that the chlorine ions initially combined with organics will be discharged as harmless sodium chloride.

The Crofton experience perhaps explains some of the inconsistencies reported in the literature, and some of the conflicting reports from mills. There have been reports of AOX reductions across secondary treatment systems that cover a 10 to 75% range. There are also reports that there are unexplained drops in AOX between the bleach plant and the entrance to the treatment system. Reasons were not identified and these inconsistencies were considered to be in keeping with AOX itself which is an inconsistent collection of chlorinated components. In these reports, there are few details of how the effluent was handled from one point to another. This is especially true for laboratory results which probably considered effluent extracted from bleached pulp to be the same as the feed to the treatment system.

Although this process is not demonstrated technology at this time, the experience explains some of the high reductions of AOX achieved in laboratory trials that could not be duplicated in the field. It also demonstrates the difficulty in trying to forecast levels of a substance such as AOX.

Patents for the method have been applied for, with the intent of recording the source of the technology. This will prevent someone else obtaining a patent for which the industry would have to pay royalties.

5.4.2 Granular filtration

Biological treatment systems lose some bio-solids, measured as total suspended solids (TSS) in the final treated effluent. Granular filtration with a variety of media can be utilized to reduce TSS discharges, with consequent reductions in BOD, nutrients and other pollutants to the extent that they travel with the solids. In the pulp and paper industry granular filtration of effluents is limited to tertiary treatment following a biological wastewater treatment process.

The equipment and process are similar to the granular filters used very widely for removal of suspended solids from municipal and industrial water supplies.

Early industry studies (Edde 1968) demonstrated that filtration should only be applied to well oxidized effluents to remove the last residuals of TSS and its associated BOD. It is generally impractical to filter raw pulp and paper mill effluents, since the quantity and fibrous nature of the solids cause rapid plugging of the filter. Biologically treated effluent with substantial concentrations of soluble BOD remaining is liable to form sufficient biological growth on the granular filter to impede operation, or at least limit capacity. The efficiency of granular filtration is dependent upon the degree of biological flocculation achieved in the secondary process. A well flocculated biological effluent, as is obtained with a properly operated activated sludge treatment system, can be filtered much more effectively than the fine solids discharged from an aerated stabilization basin. The authors are not aware of any successful full scale applications of granular filtration to ASB effluent.

The BOD removed from the effluent from the secondary treatment stage by granular filtration, following AST, can be estimated. Based on a F:M loading of 0.35 and removal of 30 mg/L volatile suspended solids (VSS) by the filter, the BOD removed would be approximately 0.28 kg BOD/kg VSS (Eckenfelder 1974). The BOD removal across the filter would be therefore by (0.28 × 30) = 8.4 mg/L BOD. If the F:M loading were higher, say 0.6, the BOD removed would be approximately 0.6 kg BOD/kg VSS and the BOD removed across the filter would be (0.6 × 30) = 18 mg/L. This illustrates the well known phenomenon that a high F:M loading in an AST system results in a more biologically active floc in the final effluent. Conversely, final effluent from a long retention (> 7 days) ASB will have a less biologically active floc in the final effluent, so that suspended solids removed by filtration would have a lesser effect on the BOD discharged.

Typical BOD and TSS removals in multi-media filter studies are presented in Table 28. The kg BOD/kg TSS removal results suggest that mills 1 and 4 are AST and mills 2 and 3 are ASB. This is a correct assumption. Although full scale filtration has been applied, following biological treatment, in at least two North American mills (Whittemore 1978), plain filtration of biologically treated effluent rarely achieves greater than 50% removal of TSS.

Table 28 Typical performance of effluent filtration pilot systems

	BOD Removal				TSS Removal		BOD: TSS
	Field		Millipore	BOD[a]			
	mg/L	%	%	mg/L	mg/L	%	
1[b]	15	30	50[c]	20[c]	40	50	0.33
2[d]	10-15	15	50	30-60	200	80	0.05-0.10
3[e]	10	25-30	30	25	40-70	55	0.14-0.25
4[b]	10-15	25-30	55[c]	20[c]	25	35	0.4-0.6

[a] Residual soluble BOD

[b] Plain filtration

[c] Estimated; based on earlier BOD (soluble) analysis of same wastewater

[d] 2 mg/L Nalcolyte added

[e] 1 mg/L Nalcolyte added

Mill experience

The Australian Newsprint Mill Limited, Albury, New South Wales, Australia (ANM-Albury) is a 220,000 tonnes per year newsprint mill that uses dual media granular gravity filters for tertiary treatment of the effluent. The filters are rated at 12 m/hr and are automatically backwashed on detection of an increase in head difference. Backwash water is filtered treated wastewater, chlorinated to prevent biological growth on the filters. Backwash water is returned to a spill pond (Thurley 1985).

The two secondary clarifiers are operated in series, and the downstream one is referred to as the tertiary clarifier (this is non-standard terminology). Granular filtration at the ANM - Albury mill is located downstream of a holding lagoon with approximately 5 days retention. TSS are measured after tertiary clarification and also after granular filtration. The long term average TSS from the tertiary clarifier is 15 mg/L. However, TSS can increase in the holding lagoon because of the activities of water birds, aquatic animals and algae growth. The long term TSS in the discharge from the final filters is 12 mg/L. There are no polymers or any other chemicals added to enhance filter performance (Personal communication with Mr. Coghill of ANM in 1991).

The ANM - Albury mill filtration beds are made up of several layers of material. Above the under-drain nozzles are two layers of gravel, sized to provide support for the filter sand. A bed of filter anthracite provides coarse filtration. This anthracite, maintains its position above the sand during the backwash operation because of its lower specific gravity. Influent flows through anthracite, then sand, then through support gravel and finally passes out through the nozzles and under drains. Table 29 presents the technical data for the filter.

Table 29 Granular filter technical data

Filter flow rate designed	4500 m³/day	
Filter bed area	15.4 m²	
Filter bed Media	**m³ volume**	**Material size**
Gravel 1	2.3	6 - 13 mm
Gravel 2	1.5	3 - 6 mm
Sand	7.7	1 - 2 mm
Anthracite	15.4	2.4 - 8 mm
Total	27 m³	
Working head: clean filter to wash point	0-2 m	
Available air supply for air scour	14 m³ @ 32 kPa	
Available water supply for waterwash	280 l/s	
Nominal water rise rate		
Stage 1	3 m/h	
Stage 2	26 m/h	
Backwash duration		
Air scour	5 minutes	
Water wash	4 minutes	
Minimum interval between washes	Probe controlled by head loss	
Maximum interval between washes	36 hours	

Table 30 presents the estimated cost of filtering biologically treated effluents. The costs would be approximately the same regardless of the type of mill production but depends on effective secondary treatment upstream. Capital and operating cost are closely related to the wastewater throughput rate and the TSS load recovered in the filter which will affect frequency of backwash requirements. Both capital and operating costs are nearly directly proportional to wastewater flow rate (Coghill 1987).

Table 30 Granular filtration capital and operating costs

Effluent flow (m^3/day)	Capital cost	Operating cost/year
10,000	$2,234,000	$348,000
30,000	$5,388,000	$936,000
60,000	$9,382,000	$1,748,000
100,000	$14,116,000	$2,769,000

Attainable effluent quality

There are relatively few data available on the performance of granular filters processing pulp and paper mill or similar effluents. While granular filtration is fairly widely used to improve the quality of municipal effluents, it is rarely applied to the effluent from well designed and operated activated sludge systems.

The following data on granular filtration performance has been assumed for the purposes of calculation in this report. The authors consider that these are the best estimates that can be developed with the information available.

TSS	15 mg/L
BOD	11 mg/L
Phosphorus	0.5 mg/L

5.4.3 Chemically assisted coagulation (CAC)

Chemically assisted coagulation is a form of tertiary treatment that may be used for additional TSS/BOD removal following biological treatment. In addition to TSS/BOD reductions, several other constituents of concern are removed by chemically assisted coagulation. The process requires a short retention time basin (approximately 10 to 20 minutes) where secondary clarifier effluent and coagulants are intermixed before entering a tertiary clarifier. The benefits of chemically assisted coagulation may include reduction of discharges of BOD/TSS, colour, AOX, dioxin, phosphorus (nutrient) and heavy metals. The major disadvantages are high costs and generation of sludge which is difficult to dewater and may contain excessive inorganic content for incineration. In a typical case, 100 to 200 mg/L alum may be added to an effluent to reduce TSS from 30 to 15 mg/L. The sludge removed from the tertiary clarifier would contain most of the alum added, so that the removal of one tonne of suspended solids would cause the production of 5 to 10 tonnes of sludge (dry weight). This sludge would carry 50 or more tonnes of water per tonne solids, and could, at best, be dewatered to about 30% consistency, resulting in the need to landfill 15 to 30 tonnes of wet sludge for each tonne suspended solids removed from the effluent.

Phosphorus

One of the principal uses of chemically assisted coagulation is for stabilizing phosphorus discharges from activated sludge plants.

Improved precipitation following the secondary clarifier in conventional biological treatment may be used to achieve lower phosphorus concentrations in the final effluent at the cost of additional sludge handling problems, as mentioned above. The sludge is not suitable for incineration because it is predominantly inorganic (although this is practised at the Hylta newsprint mill, Sweden). Cation precipitates of $Ca(OH)_2$ $Al_2(SO_4)_3$ or $FeCl_3$ are commonly used. Salts of iron and aluminium are the most commonly used.

The precipitates are removed by tertiary clarifiers (or a filter as discussed on page 216). The additional sludge mass and volume increases as the total phosphorus residual is lowered, and can reduce phosphorus concentration to less than 0.5 mg/L. Anionic polymer addition of 0.1 to 0.5 mg/L are routinely used.

The dose of the metal salt, polymer, and supplemental alkalinity required is based on observed performance. The dosages are typically set higher than needed to account for fluctuations in phosphorus loading. At low effluent phosphorus limits (P about 0.5 mg/L) violations of the regulatory requirement on a single day can raise the monthly average above allowable levels, which can lead operators to over-dosing with metal salts. To comply with low phosphorus limits, metal salt addition controls must be closely monitored.

When using alum coagulation in the presence of adequate alkalinity the chemical reaction is:

$$Al_2(SO_4)_3 + 6\,HCO_3^- \longrightarrow 2Al\,(OH)_3 + 3SO_4^{2-} + 6CO_2$$

The aluminium hydroxide floc is voluminous and gelatinous. In the presence of phosphates, the following reaction also occurs:

$$Al_2(SO_4)_3 + 2\,PO_4^{3-} \longrightarrow 2Al\,PO_4 + 3\,SO_4^{2-}$$

The phosphate removal mechanism above pH of 6.3 is either by incorporation in a complex with aluminium or by adsorption on aluminium hydroxide floc. In practice the alum dosage required depends on the final phosphorus concentration required and the chemical characteristics of the particular wastewater. The required alum dose for chemically assisted coagulation varies considerably with alum doses greater than 200 mg/L being required in some cases to realize a 1 mg/L total phosphorus residual in the chemically assisted final effluent (Culp 1971).

Cost of chemically assisted coagulation following AST

Chemically assisted coagulation by adding settling aids to the influent to the secondary clarifier represents a small capital cost and is common practice, but is limited to ensuring that the AST performs well.

A tertiary clarifier downstream of the secondary clarifier is required to realize the full potential of chemically assisted coagulation. For purposes of discussion, the capital and operating cost for phosphorus removal using alum treatment will be illustrated. In addition to phosphorus removal, suspended solids (TSS), BOD, colour and trace metals will also be reduced by varying extents. Alum coagulation avoids the problems of pH adjustment inherent with lime coagulation and avoids the difficulties associated with the use of iron salts.

Alum in the form of aluminium sulphate reacts with orthophosphate and alkalinity. Since pulp and paper industry effluents are deficient in phosphorus, the only reasonable location is after biological treatment. At the present time, there is no economical means of recovering alum from sludge and therefore it is processed and disposed of along with other sludges. As alum sludges are generally inorganic, it is not normally reasonable to incinerate them, so they become a solid waste disposal problem.

Alum can remove up to approximately 70% to 80% of the phosphorus in final effluent (Culp 1980). Actual removals are highly dependent on initial concentrations, with efficiencies dropping for inlet concentrations under 2 mg/L.

The costs for phosphorus removal by alum coagulation-sedimentation as estimated for a 40,000 m^3/day final effluent flow, are presented in Table 31. Cost indices were used to adjust the costs to current levels applicable to Ontario.

Table 31 Chemically assisted coagulation costs

Unit process	Input design parameter
Capacity	40,000 m^3/day
Pumping to chemical treatment	15 m
Alum feed, liquid (100 mg/L) $150.00/t alum	320 kg/hr
Polymer feed (0.5 mg/L) $6.40/kg polymer	20 kg/day
Rapid mix (30 seconds)	14 m^3
Flocculator (20 minutes)	550 m^3
Sedimentation	1.4 m/hr
Chemical sludge pumping (add $40/1000 m^3 for sludge disposal or $300/ton of solids)	900 m^3/day
Total capital cost	**$4,300,000**
Annual operating cost	**$1,300,000**

Source : Edde 1990

Polymers or polyelectrolytes are often added to coagulation sedimentation operations as settling aids. They increase the settleability of fine, light flocs. The selection and dose of polymers is on a trial-and-error basis, sometimes simplified by laboratory testing, but almost always requiring pilot or full-scale testing and extensive technical support.

Polymer is provided as a settling aid. Cost estimates for polymer feed systems are based on the use of dry polymer fed manually to a storage hopper located on the chemical feeder. Chemical feed equipment is based on preparation of a 0.25 % stock solution.

Chemical sludge originating in the clarifier is difficult to dewater which accounts for the high unit process cost in Table 31. Site requirements for coagulation sedimentation are typically about 100 m^2/m^3 per day. The exact space requirements will be site dependent.

Performance

The following data on chemically assisted coagulation process performance have been assumed for the purposes of calculation in this report. The authors consider that these are the best estimates that can be developed with the information available. In practice, the performance is a trade-off between costs of chemicals and sludge disposal against effluent quality. If high chemical doses are used to attain very low effluent loadings, the quantity of sludge generated can rise substantially, and disposal in an environmentally sound manner will generally be more difficult.

	30 day average	**Long Term Average**
TSS	15 mg/L	10 mg/L
BOD	11 mg/L	7 mg/L
Phosphorus	0.5 mg/L	4 mg/L

5.5 Management Practices

The design criteria and construction techniques used in developing a greenfield mill or implementing water pollution control facilities in an existing mill play a major role in protecting the environment. After the mill is operating, conditions may be revealed that could put the receiving environment at risk. A Best Management Practices Plan (BMP Plan) is targeted at identifying these specific conditions. There is also an ongoing need to monitor changes due to plant age, and modifications made to processes. A well developed plan is an environmental tool that can be useful throughout the life of a plant.

The concept of a Best Management Practice Plan is to determine the potential for toxic and hazardous chemicals to reach the receiving environment and to act appropriately. The plan involves a program of inspections and risk analyses designed to identify possible incidents that would put the receiving environment at risk, and to develop action plans to counteract any such identified risks. Effectively a Best Management Practices Plan is a collection of plans developed to take preventive measures for protecting the receiving environment from potential risks including those not covered explicitly by discharge permits and control orders.

A plan involves reporting incidents, materials compatibility, good housekeeping, preventive maintenance, inspections and records, security, and training. Each of these areas is a normal function of mill management in a well managed mill. A BMP Plan formalizes these practices. Best Management Practices are centred around actions and not targets.

6 EMERGING TECHNOLOGIES

6.1 Towards Zero Effluent

SUMMARY Technology is now emerging which will probably make the operation of zero-effluent mechanical pulp mills feasible in the near future. The costs appear to be in the same order as advanced biological treatment, but operating experiences will be required to confirm this. Data should be available by the end of 1992. It is currently technically feasible to operate some board mills with zero effluent, and to approach very close to this environmental ideal for corrugating medium mills.

6.1.1 Concepts of zero effluent

The terms "zero effluent" and "effluent free" have been used and misused frequently over the past twenty years. These term are considered as synonymous in this report and this report defines **"zero effluent" to mean elimination of liquid process effluents from a pulp or paper mill, without transferring an unreasonable load to the airshed or soil.** Cooling water which has not been in contact with the process, sanitary effluents and storm water run-off would still exist in a zero-effluent mill.

Several projects are under way worldwide where established corporations have committed to building zero-effluent pulp or paper mills. The suppliers of the equipment used are generally well established in the industrial process field, and are offering hardware that has been well proven in similar, but not identical, conditions. The modifications to conventional manufacturing process are evolutionary rather than revolutionary in nature. **The authors class this as emerging technology which may be applicable in some Ontario mills in the near future,** but is not yet sufficiently mature to be considered as demonstrated technology.

In most cases, the essence of a zero-effluent design is to modify the production of traditional processes to reduce the effluent volume to around 10 m^3/tonne product, and then evaporate this effluent, incinerate the concentrate, and reuse the evaporator condensates as mill water supply. For over 50 years kraft mills have been evaporating around 10 m^3/tonne weak black liquor containing about 14% dissolved solids, per tonne of product . Mechanical pulp mills and deinking plants have been built which currently operate with under 10 m^3 effluent per tonne product.

Dry debarking is essential, unless the mill operates entirely with purchased chips or purchased pulp. However, the costs of modifying any existing woodroom and, in some cases, upgrading the mill's pulp screening and cleaning systems to modern standards, would be significant, and should be properly considered in any economic analyses.

The only operating zero-effluent mills the authors are aware of, in the world at present, are board mills which can afford to include a significant quantity of diverse dissolved solids and some solid contaminants in their product.

The possibilities of attaining zero effluent in mechanical pulp mills and in bleached kraft mills are discussed below in further detail.

6.1.2 Kraft mills

Today, a well designed unbleached kraft mill should in principle be able to operate with zero effluent. However the authors were unable to find an example, perhaps because no mill has been required to do so, or been faced with extremely restrictive discharge regulations simultaneously with the time to develop a closed operation instead of installing a biological treatment system.

The Rapson process for closing up a bleached kraft mill has been tried in Ontario and was abandoned due to pitch build-up, corrosion problems arising from the use of chlorine compounds in the bleach plant and operational complexity. Once the chlorine compound free bleaching process is developed, prospects for a zero effluent bleached kraft mill will look more promising.

6.1.3 Paper mills

A paper mill that uses only purchased virgin pulp as furnish can be built to operate with very little effluent. The Kimberly-Clark mill at Huntsville discharges only about 4 m^3/tonne product. The only real impediment to eliminating the effluent by evaporation is that it is so lightly contaminated that there is no environmental reason to do so. The low effluent discharge at Huntsville is due to the application of engineering and operational ingenuity to profit from the unusual advantage that the mill uses only fully bleached kraft pulp which is produced off site. The technology is not transferable to any other Ontario mill, although some elements could be of interest elsewhere.

When the mill uses fillers or coatings, the problems would be more difficult. Probable solutions would include a tight water balance, flocculating clarifier to remove suspended materials as sludge, and evaporation and/or freeze crystallization to remove dissolved solids. In general there is probably little environmental need for such an approach.

If there is an integrated pulp mill, then it may be necessary to minimize the input of dissolved solids to the paper mill. This can be done by dewatering the pulp to a reasonably high consistency, perhaps 12% or even the 40%, attainable in modern presses.

6.1.4 Semi-chemical / corrugating medium mills

These are essentially integrated mills, with the added complication of a high-yield pulp, which generates significant quantities of inorganic and organic solids. Many mills of this type operate with a BOD of only a few kg/tonne product by concentrating and burning the waste liquors and operating with a very tight water balance.

The corrugating medium mill, Green Bay Packaging Inc., Wisconsin, was operated for several years with a BOD discharge of under 1 kg/tonne product, without any external effluent treatment (Mill visited by one author in 1989 and further personal communication with the mill in 1990 and 1991). There are no data available on the toxicity of the effluent, but since the BOD was under 10 mg/L, and consists of volatile organics from the paper machine vacuum pumps, it seems unlikely that the LC_{50} would be over 100%. This was, therefore, not an effluent free-mill, although it discharges very much less BOD than most corrugating medium mills with conventional external secondary treatment systems. On January 1st, 1991 Green Bay Packaging started a completely new linerboard operation based on secondary fibres, see page 185. The mill is in the process of closing this new operation to zero effluent.

In Europe, there is a trend toward eliminating virgin pulp for manufacturing corrugating medium in favour of secondary fibres (EC 1989). Appendix C gives one example, the Grenaa Papfabrik AS, Denmark, which has run zero-effluent for the last two years. This mill also produces linerboard and other paper products for packaging materials from secondary fibres.

As indicated in Appendix A, the only corrugating medium mill in Ontario with a secondary treatment system, MacMillan Bloedel Inc. at Sturgeon Falls, discharges substantially greater quantities of BOD than the Green Bay mill did while manufacturing NSSC based corrugating medium.

6.1.5 Deinking mills

It appears that the lowest practicable effluent flow for a deinking mill is about 8 m^3/tonne product at present. While this is within a reasonable range of costs for evaporation, the authors are not aware of any projects or serious engineering study to do so. The aqueous discharge from deinking plants is relatively insignificant, so no major developments toward zero effluent in the near future are seen. The flocculating clarifier system for concentrating the deink sludge is more water efficient than the older washing systems. The authors consider that the Best Available Technology for control of deinking mill process effluent would be to design the systems for an effluent flow under 10m^3/tonne pulp and treat the effluent by AST, with perhaps a granular filter following.

6.2 Zero Effluent Mechanical Pulp Mills

6.2.1 Current status of technology

Two mechanical pulp mills are under construction at the time of writing which are designed to operate without any planned process effluent. The systems are designed to store and recover spills, so that they are expected to operate without any process effluent at all.

Both mills will produce bleached chemi-thermomechanical pulp (BCTMP) which will be flash dried for sale on the market. Bleaching will be entirely by hydrogen peroxide. The companies marketing activities have made it clear that they see the absence of chlorine compounds as a marketing advantage.

One mill, at Meadow Lake, Saskatchewan, is owned by Millar Western, and start-up is scheduled for late 1991.

The other mill, at Chetwynd in North Eastern British Columbia is owned by Louisiana Pacific Corp. It uses an alkaline peroxide CTMP process which avoids using sulphur. The mill flowsheet has been balanced for 11.3 m^3/tonne product effluent. The latter will be concentrated to approximately 15% consistency by a freeze crystallization process which will produce very pure water (under 200 mg/L dissolved solids and under 2 mg/L TSS). The 15% consistency liquor produced will be evaporated and incinerated. The mill is described in some detail by Barbe (1990).

According to telephone contacts made in August 1991, the plant was partially operational, and minor start-up problems were being resolved. The operations were not sufficiently stable for any assessment of success or otherwise .

6.2.2 Feasibility in Ontario

As discussed in Appendix E, it would be necessary to minimize the total effluent flow from a newsprint mill for this process approach to be potentially viable. If an Ontario mill achieved the 12 m^3 discharge flow of the Hylta mill (Appendix C), then the cost of the zero effluent system for a 500 tonne per day mill would be in the order of $50 million, and the operating costs relatively high. Further technical developments will be required if this approach is to become viable for a newsprint mill. Presuming that the operations at Chetwynd continue satisfactorily, the process will merit evaluation for any future market CTMP mills in Ontario.

6.3 Kraft Mill Pollution Prevention at Source

Several emerging technologies that are not yet installed in operating mills appear promising.

Emerging modifications will assist in improving the characteristics of kraft mill effluents, without in themselves leading to elimination of chlorine compounds. These are discussed below.

6.3.1 Hot alkali extraction

During his presentation at the TAPPI environmental conference in San Antonio, April 1990, Gullichsen described a process modification under study in the Helsinki University of Technology which could potentially be used to reduce the unbleached Kappa number of pulp.

The process relies on the fact that some of the lignin in unbleached kraft pulp is generally considered to be undissolved, and hence not washable with water. Gullichsen considers that in fact, the lignin is in solution within the pulp fibres, and can be liberated by soaking for about half an hour in sodium hydroxide solution at approximately 150 deg C. He proposed to use black liquor in practice, fortified with sufficient white liquor to raise the sodium concentration to approximately 2 g/L. Apparently Nils Hartler of STFI has proposed a similar process, but the authors were unable to obtain further information in the time available.

On an industrial scale this would require a pressure vessel in line with a continuous digester, operating slightly below digester pressure. For a 500 tonne/day digester line this would be approximately 4 m diameter by 8 m high. This is a practical size for a shop fabricated pressure vessel. It would be inappropriate to estimate costs until the process is better defined, and the actual process requirements are known. Rough calculations indicate that this could potentially be an easily retrofittable, relatively low cost means of reducing Kappa number.

Gullichsen indicated that a drop of several points in Kappa number would be attainable, but that further laboratory work was required before field trials could commence.

The effects on the kraft recovery cycle would presumably be similar to those of extended cooking discussed previously, increasing the quantity of black liquor burned by a few percent. For mills with adequate recovery boiler capacity, there would be a net gain in energy, while for a mill with limited recovery boiler capacity, some, perhaps costly, measures would be required to accommodate the increased liquor volumes.

6.3.2 Enzyme pulping / prebleaching

SUMMARY Laboratory trials have shown that enzymes remove lignin from pulp, thus reducing the Kappa number, without the use of chlorine compounds. Pulpzyme-HA is one potentially useful enzymatic product. Full-scale testing is being conducted at the time of writing, and this technology cannot be considered "demonstrated" for another year at least.

As wood is a natural product, it is potentially possible to utilize enzymes in the preparation of pulp. Fungi and other microorganisms are basically doing the same job, under very mild conditions in nature, as strong chemicals and vast amounts of energy are doing in the pulp mill. Normally the action of fungal enzymes that can be observed in chip stacks is unwanted, but these same enzymes could potentially become useful if properly controlled.

The enzyme pulping process itself is difficult to control due to the mechanical problems of bringing the enzymes into contact with the inner part of a wood chip. There have been reports on using white rot fungi to do this job, but the results are too poor to justify classifying the process as "an emerging technology" at this stage.

Several companies worldwide have shown interest in developing enzymatic products for the pulp and paper industry, including Novo Nordisk (Denmark), I.C.I. (Canada and UK), Sandoz (USA), and Iogen (Ottawa).

Novo Nordisk Inc. is one of the largest producers of enzymes and have provided information discussed below. The field is quite competitive, and much of the know-how is considered proprietary, but will presumably become more readily available if and when practical commercial operations are developed. The biggest single product of Novo Nordisk is the proteolytic enzyme for washing powder, but they manufacture a range of products including insulin. When environmental pressure increased on the pulp and paper industry to reduce water effluent burdens in the mid 80s, Novo Nordisk started developing enzymatic products for the sector, and market three such products:

Resinase A 2X
Novozym 342
Pulpzyme-HA

The following information is taken from Novo Nordisk research reports which may be obtained from the company (Novo Nordisk 1991).

Application of the Pulpzyme-HA for pulp bleaching has been tested in full scale in Finland. Pulpzyme-HA is a xylenese preparation derived from a selected strain of *Trichoderma reesei*. It contains endo-1,4-ß-D-xylenese as well as exo-1,4-ß-D-xylenese activities. Pulpzyme-HA has a certain amount of cellulase activity, which affects the viscosity of the pulp and thus limits the amount of enzyme that can be used, although the activity towards crystalline cellulose is low. In the original preparation the cellulase activity was at a maximum around pH 5 to 6, and xylenese had its maximum activity around pH 4, so a pH below 4 had to be obtained during full-scale trials. Furthermore, active chlorine can react with the enzyme protein and thereby destroy its catalytic site, so Pulpzyme-HA had to be used with less than 1 ppm molecular chlorine present. Today Novo Nordisk has a preparation in which the cellulose activity has been considerably reduced, so even higher amounts of enzymes can be used at higher pH values than previously. The enzyme is still sensitive to active chlorine, and experiments have shown the activity to be supplementary to the activity of oxygen delignification, i.e. better results have been obtained on oxygen delignified pulp than normal, unbleached pulp. Therefore, Pulpzyme-HA should be used in a separate stage after the O-stage and after washing, and an efficient washer should direct the spent enzyme liquor to the recovery plant prior to the first D_C-stage.

In the original test in 1989 an oxygen delignified hardwood kraft pulp was treated with 0.17% Pulpzyme-HA for 3 hours at 50 deg C, pH 5 to 6 and 10% consistency. A possible saving of 35% of the active chlorine in the first C/D-stage was reported, and the brightness was elevated 1% to 2% ISO in a 3-stage sequence without serious effects on the pulp strength properties. A similar experiment in 1990 on oxygen delignified softwood reported possible savings in active chlorine of up to 18%.

Tolan (1991) reported similar figures from Canadian pilot plant trials with a conventional pulp in the C_dEDED sequence, which used 5 to 7 kg xylenese enzyme per tonne pulp.

6.3.3 Lignox process for bleaching

The Lignox *process is an emerging technology which uses hydrogen peroxide with a chelating agent pre-treatment to lower the Kappa number of oxygen delignified kraft pulp by about 40%. The* Lignox *bleached pulp can be marketed as semi-bleached kraft, or bleached to full market quality with chlorine dioxide, while discharging under 0.3 kg AOX/tonne pulp. One full scale trail operation is running in a small Swedish mill, but they have not yet been able to sell the full pulp capacity of* Lignox *bleached pulp. The* Lignox *process is a low capital/high operating cost approach to reducing AOX, which is applicable only in mills already practicing oxygen delignification.*

The environmental significance of the Lignox *process is not yet established. There is no doubt that it can reduce AOX by up to 50%, in suitable circumstances. However questions as to the environmental significance of the EDTA discharges, and the acute lethality of the* Lignox *effluent remain unanswered. As presently operated, the Lignox process does not reduce the organic discharges from a mill.*

The *Lignox* process was developed by Eka-Nobel, a major supplier of technology and chemicals to the pulp and paper industry. **The authors of this report recognize that Eka, or associated organizations are proprietors of the process, and the description herein is purely for readers' convenience.**

The objective of the *Lignox* process is to reduce the Kappa number of pulp so that it can either be marketed as semi-bleached, chlorine-compound-free pulp, or else further bleached with chlorine dioxide and other agents to produce a fully bleached pulp with low organochlorine emissions. The chlorine-compound-free *Lignox* pulp has a maximum brightness of about 70 to 75 ISO, and if it could be marketed in this semi-bleached condition, then there would be no AOX discharge. If the pulp is subsequently bleached with chlorine dioxide to approach 90 ISO, then AOX discharges can be expected to be well under 0.5 kg/tonne pulp.

The principal bleaching chemical used in the *Lignox* process is hydrogen peroxide, which has been used to bleach kraft pulp for many years. The distinguishing features of Eka-Nobel's process are the use of chelating agents prior to the addition of the hydrogen peroxide, and the operation of the hydrogen peroxide stage at relatively high temperatures and with long retention time.

The flowsheet on page 234 depicts the *Lignox* process applied to a typical kraft mill, similar to that shown on page 168. Notice that both mills incorporate oxygen delignification, since this is a pre-requisite for the *Lignox* process. In the chelating stage, identified as "EDTA" in the flowsheet, chelating chemicals and sulphuric acid are added to complex the trace quantities of metals that are normally present in kraft pulp, so that they can be washed out in the subsequent washer, and to ensure that those that remain with the pulp will not interfere with the subsequent hydrogen peroxide bleaching stage. The most commonly used chelating agent is ethylene-diamine-tetra-acetic acid (EDTA) but diethylene-triamine-penta-acetic acid (DTPA) and several proprietary compounds have also been investigated (Basta 1991).

The initial EP-stage would have a 2 to 4 hour retention time, and the choice of materials in the process equipment is of the utmost importance to avoid metals interfering with the bleaching reaction. Recent work by Basta (1991), confirmed by PAPRICAN (personal communication, B. van Lierop, 1991) indicates that this stage must operate at 90 deg C, and have a 4 hour retention time.

Where fully bleached pulp is required, three subsequent stages, D (EP) D, or a similar sequence can be used to attain market brightness (ISO 89 to 90).

Ultimately the process may be developed to produce market pulp without the use of chlorine compounds, but the data presented on the fully bleached pulp trials at the only operating installation of *Lignox* (Munksjo, Aspa, Sweden) indicated the need for 16 kg chlorine dioxide per tonne pulp to reach 89.1 ISO brightness (Basta 1991). The AOX discharge was stated to be 0.3 kg/tonne. The mill concerned does not have a secondary treatment system, but if it had, one would expect that the final AOX discharge would be about 0.2 kg/tonne pulp. At Aspa, the fully bleached pulp was manufactured using the sequence Q EP D EP D. It is interesting to note that the final three stages discharge 0.3 kg AOX/tonne pulp, while comparable stages following a conventional bleach plant front end discharge essentially no AOX.

The brightness after the initial EP-stage is ISO 70% to 75%. This is sufficiently bright for sale of semi-bleached pulp, and in 1990 8% of Aspa Bruk's production was chlorine-compound-free. In 1991 this figure is expected to reach 20% of the total production of 95,000 tonnes/year. This quantity of chlorine-compound-free pulp (19,000 tonnes) will represent 0.06% of world market kraft capacity.

At the time of writing, Aspa Bruk were running the *Lignox* plant on an experimental basis, in that they did not have the final operating permit. Södra Skogsägarna[64] indicated during public hearings concerning their Mönsterås mill that they had run laboratory trials on the *Lignox* process with no success - they reported major difficulties in controlling the quality of the pulp. A later press release reported in Svensk Papperstidning (#9, 1991 issue) that 1500 tonnes of pulp bleached with hydrogen peroxide instead of chlorine had been produced at the Mönsterås mill. The company's research director, S. Moldenius, stated "We have already realized that we will not be able to attain the same level of brightness attained as when using chlorine. Now we shall investigate strength properties, and the potential market for this product. Interest in chlorine free pulp has increased over the past several years".

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[64] *A major Swedish pulp producer, competing with Aspa.*

In the same press report, the Mönsterås mill manager reportedly stated, "I am not sure whether customers are willing to pay more for the chlorine free pulp when compared with their normal pulp. It is more expensive to use this method compared to the old method. This is the first step in a very long investigation to produce chlorine free pulp."

Work is continuing, obviously with hopes of success. Aspa Bruk is continuously working on quality and economy improvements, especially improved delignification in the first EP-stage by increased retention time and higher consistency.

Environmental impacts

The only tests of acute lethality that the authors were able to find indicated that the LC50 is very low, but the laboratory concerned declined to have the results published, in view of their preliminary nature. It will be essential to establish the LC50 of the wastewaters and their effect on the toxicity of biologically treated effluent before the process could be considered in Ontario.

The flowsheet on page 234 indicates that effluents from the chelating and first peroxide stages may optionally be recovered by recycling to the pulp washing system and from there to the recovery boiler with the black liquor. However, this has not yet been accomplished at Aspa, and the publications on the *Lignox* process are silent on the issue. If recycled as shown, then some of the metals removed from the pulp would be recycled to the input of the chelating stage. It is not yet known whether the effects of this on the operations would be acceptable or not. Other possibilities exist, and will presumably be investigated.

The environmental benefits of recycling the organics from the chelating and EP stages to the kraft mill's recovery boiler are obvious. However, questions such as the effect of the chelating agents on the mill's ability to evaporate the black liquor, the fate of the recycled metals and other presently unknown operating problems may make this impractical. A full-scale mill trial is obviously essential to establish the feasibility of recycling this material. The fact that this has not been undertaken at the *Lignox* plant at the Aspa mill is a question which remains unanswered at the time of writing.

There were not sufficient data available for the authors to calculate mass and energy balances for the *Lignox* process similar to those calculated for the emerging ozone delignification technology, but a preliminary estimate of the direct operating costs is presented below.

In view of its chelating properties, concerns have been expressed about the possibility of causing environmental damage by releasing EDTA, but analysis of this issue is beyond the scope of this report.

Capital costs of *Lignox* process

The *Lignox* process can be implemented in a 5-stage bleach plant by changing (DC) (EOP) D (EP) D to Q (EP) D (EP) D. Figure 41 shows how the process could be adapted to the flowsheet for a conventional bleached kraft mill equipped for oxygen delignification shown in Figure 32 on page 168. If the following conditions exist, then the capital cost could be quite low relative to alternative means for reducing the Kappa number of the pulp prior to final bleaching:

An oxygen delignification system exists
Bleach plant metallurgy does not require modification
Sufficient retention time (4 hours) is available in existing bleaching towers.

None of the nine kraft mills in Ontario satisfy all of the above requirements.

Table 32 Preliminary estimate of operating costs for *Lignox* bleaching

Item	Unit cost	Quantity	Cost
	$/kg	kg/tonne pulp	$/tonne pulp
Chelating stage			
Acid for pH control	$0.13	6	$0.78
Chelating agent (EDTA)	$1.40	2	$2.80
E1/peroxide stage			
Sodium hydroxide	$0.35	23	$8.05
Hydrogen peroxide	$1.32	25	$33.00
Operating consistency		11%	
Process steam (50 ---> 90 deg C)	$9.00	0.66	$5.98
Sub-total cost to end of *Lignox* stages			$50.61
First chlorine dioxide stage			
Chlorine dioxide	$1.02	10	$10.08
Sulphuric acid	$0.13	3	$0.39
E2/peroxide stage			
Sodium hydroxide	$0.35	4	$1.40
Hydrogen peroxide	$1.32	2	$2.64
First chlorine dioxide stage			
Chlorine dioxide	$1.02	5.7	$5.82
Sulphuric acid	$0.13	3.	$0.39
Total cost of bleaching chemicals and energy			$71.33

Unit costs are typical Ontario prices in mid 1991, and chemical quantities are based on Basta (1991)

The costs for implementing oxygen delignification are well known, but there is not yet sufficient information available to calculate a credible estimate for the costs of the modifications to the bleach plant metallurgy which would be required to implement the *Lignox* process successfully in Ontario. One indication of the technological uncertainty concerning the process is that the publication of information on the production of fully bleached pulp using the *Lignox* process was delayed due to the time required to make the necessary in-plant process changes to meet supplier and mill objectives (Comment by Hans Fasten, manager of Aspa mill, at the Pulp Bleaching Conference, Stockholm, June 1991).

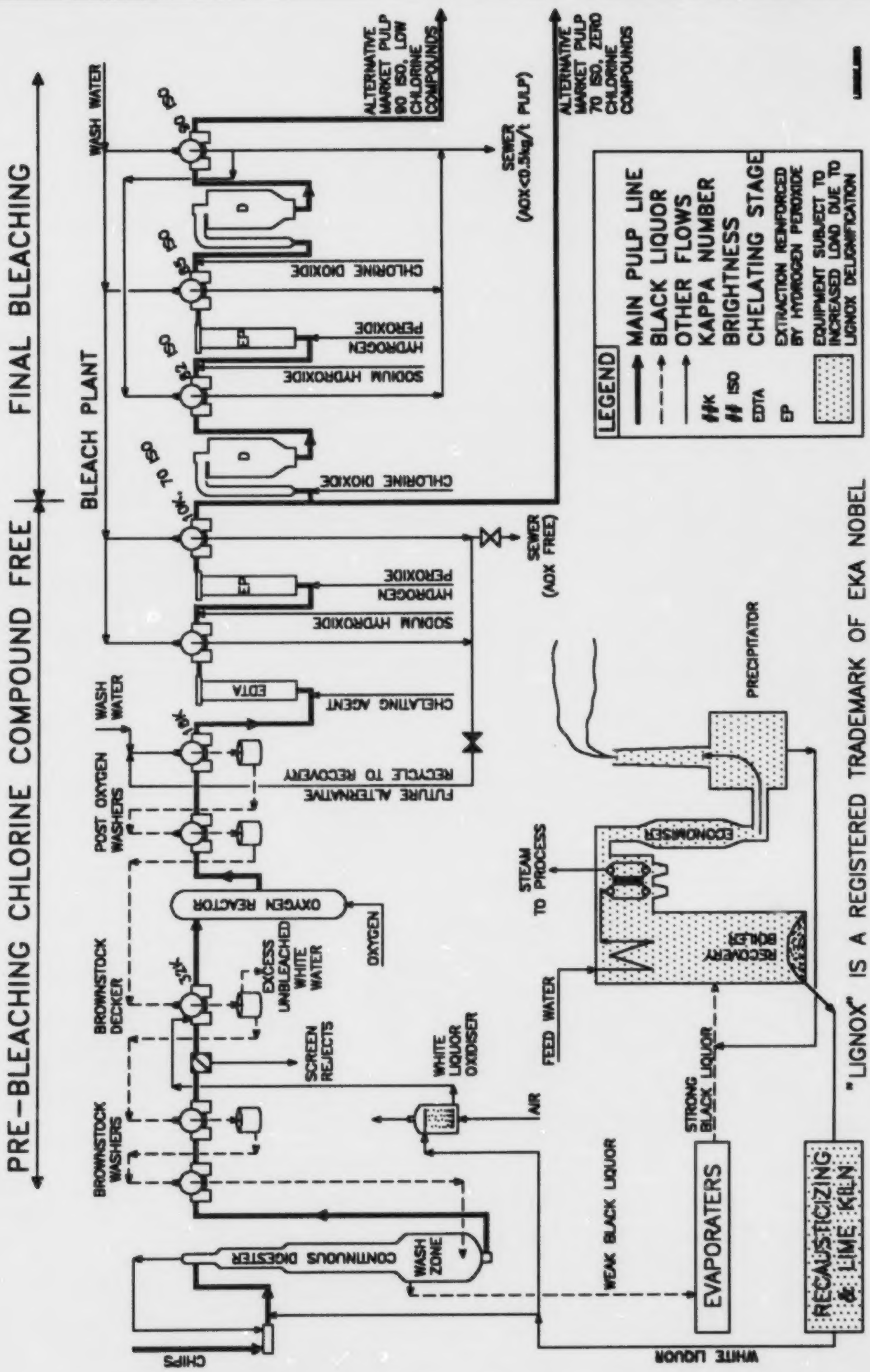
PRE-BLEACHING CHLORINE COMPOUND FREE
FINAL BLEACHING
BLEACH PLANT
WASH WATER
BROWNSTOCK WASHERS
SCREEN REJECTS
BROWNSTOCK DECKER
32K
EXCESS UNBLEACHED WHITE WATER
OXYGEN REACTOR
OXYGEN
POST OXYGEN WASHERS
WASH WATER
10K
EDTA
CHELATING AGENT
FUTURE ALTERNATIVE RECYCLE TO RECOVERY
SODIUM HYDROXIDE
EP
HYDROGEN PEROXIDE
SEWER (AOX FREE)
10K 70 ISO
D
CHLORINE DIOXIDE
SODIUM HYDROXIDE
EP
HYDROGEN PEROXIDE
EP
CHLORINE DIOXIDE
D
90 ISO
EP
WASH WATER
SEWER (AOX<0.5kg/t PULP)
ALTERNATIVE MARKET PULP 90 ISO, LOW CHLORINE COMPOUNDS
ALTERNATIVE MARKET PULP 70 ISO, ZERO CHLORINE COMPOUNDS
CHIPS
CONTINUOUS DIGESTER
WASH ZONE
WHITE LIQUOR
WHITE LIQUOR OXIDISER
AIR
WEAK BLACK LIQUOR
EVAPORATERS
STRONG BLACK LIQUOR
FEED WATER
RECOVERY BOILER
STEAM TO PROCESS
ECONOMISER
PRECIPITATOR
RECAUSTICIZING & LIME KILN
LEGEND
MAIN PULP LINE
BLACK LIQUOR
OTHER FLOWS
#K KAPPA NUMBER
# ISO BRIGHTNESS
EDTA CHELATING STAGE
EP EXTRACTION REINFORCED BY HYDROGEN PEROXIDE
EQUIPMENT SUBJECT TO INCREASED LOAD DUE TO LIGNOX DELIGNIFICATION
"LIGNOX" IS A REGISTERED TRADEMARK OF EKA NOBEL

Figure 41 Lignox molecular chlorine free process applied to typical kraft mill

Based on full scale pilot plant system at Aspa, Sweden 1991. Other parts of mill would be as shown on Figure 32.

Ozone delignification and retrofitting extended cooking are the only two processes which currently appear realistic to achieve goals similar to *Lignox* with respect to organochlorine discharges. The former is proven on the pilot plant scale, the latter is demonstrated technology.

Eka-Nobel, the proprietors of the *Lignox* process advised in April 1991 that they do not expect to be able to provide definitive capital cost information for Canada for some months.

The authors estimated that in a *Lignox* based bleach plant, the cost of bleaching chemicals and additional steam for pulp heating. would be over $70/tonne pulp, as shown in Table 32. An Ontario mill which installed the oxygen delignification stage, which *Lignox* would require, could manufacture bleached pulp of similar or better quality with the expenditure of only $25/tonne pulp for chemicals and steam.

6.3.4 Chlorine compound free bleaching with ozone and hydrogen peroxide.

As indicated previously, processes based on oxygen delignification and ozone appear to offer the possibility of commercial production of chlorine compound-free bleached kraft pulps. Lachenal (1988) and other authors have stated that ozone delignification "activates" the pulp for subsequent bleaching by hydrogen peroxide. Sixta (1991) published data on bleaching spruce in the laboratory with an $OZE_{op}ZPZP$ sequence to market quality. This sequence used the following chemical charges:

Ozone	9 kg/tonne pulp
Sodium hydroxide	30 kg/tonne pulp
Hydrogen peroxide	13 kg/tonne pulp

If a typical allowance for steam is included, this would represent approximately $45/tonne pulp at current Ontario prices, which is similar to current kraft pulp bleaching costs in Ontario mills. However, if a mill had installed oxygen delignification and extended cooking, then the bleach chemical cost would be about $25/tonne, so that installation of an ozone delignification system would probably increase bleaching costs somewhat. Readers are warned that the variation in bleach costs is such that it is essential to carry out laboratory trials to determine the actual chemical consumptions required to bleach local wood to customer specifications. The only conclusion concerning the economics of the process that should be drawn from Sixta's data above is that it would not be unreasonable for Ontario mills to investigate ozone delignification in the expectation that the chemical costs may be acceptable relative to the environmental and cost benefits associated with eliminating chlorine.

6.3.5 Costs of ozone delignification

It would be premature to estimate capital and operating costs for ozone delignification systems, since the necessary industrial experience is lacking. Preliminary indications are that a retrofit to a 500 ADt/day bleach line would cost in the order of $10 million, assuming that the ozone generator is leased. Oxygen delignification is a prerequisite, and the problem of recovery boiler capacity to burn the additional solids would add significantly to the cost in some mills, while being insignificant in others.

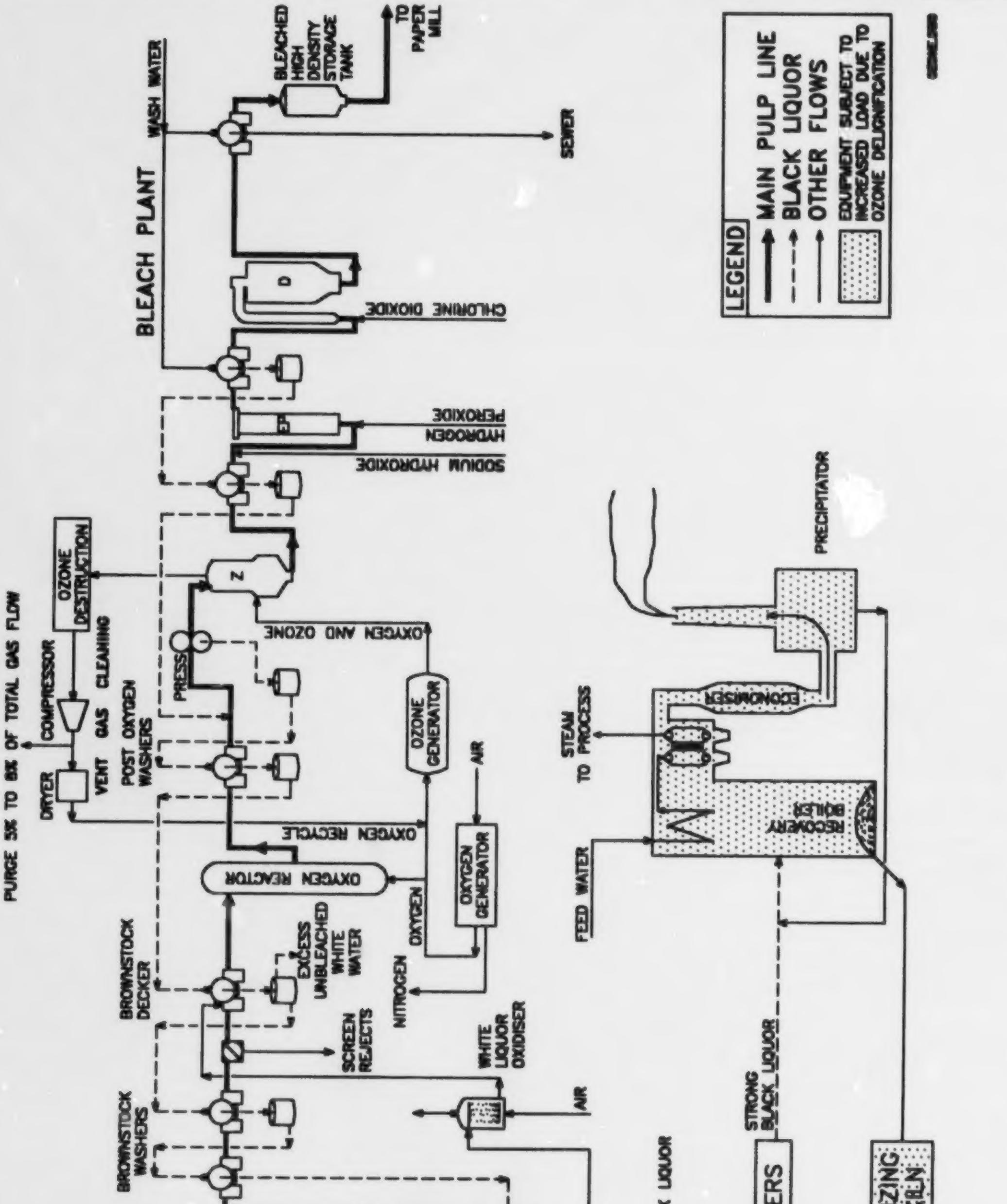
CHIPS
CONTINUOUS DIGESTER
WASH ZONE
BROWNSTOCK WASHERS
SCREEN REJECTS
BROWNSTOCK DECKER
EXCESS UNBLEACHED WHITE WATER
NITROGEN
OXYGEN
OXYGEN GENERATOR
AIR
OXYGEN REACTOR
OXYGEN RECYCLE
POST OXYGEN WASHERS
OZONE GENERATOR
PRESS
OXYGEN AND OZONE
Z
PURGE 5% TO 8% OF TOTAL GAS FLOW
DRYER
VENT GAS CLEANING
COMPRESSOR
OZONE DESTRUCTION
SODIUM HYDROXIDE
HYDROGEN PEROXIDE
EP
CHLORINE DIOXIDE
D
BLEACH PLANT
WASH WATER
SEWER
BLEACHED HIGH DENSITY STORAGE TANK
TO PAPER MILL
LEGEND
MAIN PULP LINE
BLACK LIQUOR
OTHER FLOWS
EQUIPMENT SUBJECT TO INCREASED LOAD DUE TO OZONE DELIGNIFICATION
WHITE LIQUOR OXIDISER
AIR
WEAK BLACK LIQUOR
EVAPORATERS
STRONG BLACK LIQUOR
RECAUSTICIZING & LIME KILN
WHITE LIQUOR
FEED WATER
RECOVERY BOILER
STEAM TO PROCESS
ECONOMISER
PRECIPITATOR

Figure 42 Kraft mill with ozone delignification stage

It appears probable that the direct operating costs will be lower than for conventional bleaching of oxygen pre-bleached pulp, by several dollars per tonne.

6.3.6 Commercial developments

Union Camp Corporation

As discussed in Appendix C, Union Camp Corporation is currently constructing a 900 tonne/day kraft bleach line at their integrated Franklin, Virginia mill, with start-up scheduled for late 1992. The company has announced that they will licence the technology to any paper company. Union Camp has entered into a technical and marketing alliance with Sunds, a well established manufacturer of a variety of pulping and bleaching equipment.

The new Franklin bleach plant is a replacement for two 40 year old lines that are still in reasonably good physical condition, but considered obsolete by the company. The mill effluent currently complies with local regulatory requirements. It is therefore a good location for innovation, and resolution of the technical difficulties inherent in most new processes, with minimal risk of a catastrophically expensive loss of production if the ozone stage suffers from a long learning curve on start-up.

IMPCO

Impco were active in the development of ozone delignification technology in the mid 1970s, and ran a 25 tonne/day pilot plant in the S.D. Warren mill at Muskegon, Michigan at that time. This was processing hardwood pulps which had NOT been oxygen delignified. The trials were reportedly successful, but no commercial installations followed.

At that time, US regulations were focussed on BOD and suspended solids, with some public concern being expressed about effluent colour. Organochlorines, dioxins, and the wide variety of persistent substances which are of concern to the MISA program were not normally considered significant by the regulatory authorities when writing permits and regulations in the 1970s. All US pulp mills had to install biological treatment, and there was no possibility of any mill complying with EPA and State requirements by installing improved bleaching without biological treatment. Therefore, mills generally found the "external treatment" approach less expensive.

IMPCO are now actively marketing ozone delignification systems, and advise that they would be willing to sign a contract to supply, install and guarantee one in a North American mill.

Kamyr

Kamyr Inc is the dominant supplier of continuous digesters for kraft pulp, and a major supplier of several other components of the pulping/bleaching areas of kraft mills. At the time of writing, they are installing a 10 tonne/day ozone delignification pilot plant in the E.B. Eddy mill at Espanola. This is based on medium consistency processing (around 12%), in contrast to the Sunds and Union Camp approaches which are based on high consistency operation. Medium consistency processing will probably require greater quantities of ozone than high consistency, but this and other critical considerations such as pulp quality and process stability cannot be resolved without a pilot plant.

Kamyr have advised that they hope to be able to quote and guarantee full scale ozone delignification plants by late 1991. Obviously, this is predicated on their being able to resolve the inevitable unforeseen problems in the pilot plant without undue delay.

Voest Alpine

This major European manufacturer of pulp mill systems has announced an aggressive development program for ozone delignification systems (Schwarzl 1991). They are apparently concentrating on a medium consistency system which uses ozone dissolved in water as the bleaching agent, and avoids the need for the relatively complex and expensive recovery systems for the oxygen vented from most ozone reactors. While their innovative approach may prove to have operational and cost advantages, there are no obvious environmental differences, so the authors have not investigated it in any detail.

6.4 Organosolv Pulping

There are a number of emerging or new pulping processes that are promoted as being environmentally friendly by their supporters. This group includes Organocell, Stake, Alcell, Ester, ASAM, Pollution Free Process, Milox and Oxygen-Alkali. Some of these have been around for 20 years or so while others have just come on the scene. None are demonstrated technologies, and there is no evidence of significant environmental advantages for those which have reached the continuous pilot plant stage of development.

6.4.1 Alternative pulping processes

The Pollution Free Process was a Japanese development in the early 1970s aimed at replacing kraft pulping. Besides corrosion problems, the electrical and steam energy consumption was very high and the process apparently progressed no further. The Oxygen-Alkali process (Rodden 1990) is a recent Soviet pulping process that is in the very early stages of development. The Stake Process (Barbe 1990) is not intended to be a replacement of kraft but it may allow semichemical pulps to replace some additional chemical pulp. The other processes are variations of solvent pulping.

The Alcell (Pye 1991), Ester (Young 1989), and ASAM (Patt 1987) processes may be considered solvent pulping under acidic conditions. These processes are reported to produce pulps that are superior to sulphite or are equivalent to hardwood kraft, but they do not appear ready to replace softwood kraft. The Milox pulping process (Jokinen 1991) is a low temperature treatment with hydrogen peroxide and formic acid. Little technical information has been published. A $2.5 million pilot plant is planned to further develop the process. The Organocell process is solvent pulping involving alkali. Sarkenen (1990) believes that the reactions would probably follow a course similar to soda pulping, but he states that the chemistry of the process has not been completely characterized. This process has gained a great deal of attention and is treated in more detail below.

6.4.2 Organocell

Although solvent pulping has been known to be technically possible since 1931, Sarkanen believes that it was not considered seriously until recently. This is reflected by the Organocell process. The initial research on this process was undertaken in 1977 by Technocell AG, at the time a member of the MD Group (West Germany) as outlined in Organocell sales literature. The German Federal Ministry for Research and Technology agreed to support the project.

Research led to a 5-tonne per day demonstration plant operating successfully since 1987. This was a 2-stage cooking process until 1991 when it was changed to a single stage process. This change has delayed the start-up of a new 310 tonne per day plant at Kelheim (near Munich). The original start-up reported by Dahlmann (1990) was November, 1991 and has now been delayed until early 1992.

The process is sulphur-free and uses a mixture of methanol, water, and sodium hydroxide. All types of wood are reported to be pulped successfully. Most chemicals are recovered and reused. The recovery of methanol from the cooking liquor must take into account the fact that methanol is a flammable liquid. The entire pilot plant was built to be explosion proof. The new commercial plant will be designed to remove the solvent from the black liquor as soon as possible. The area that will come under the explosion proof code will be therefore kept to a minimum.

The pulp product is stated to have properties comparable to sulphate pulps. Dahlmann (1990) compares Organocell pulp with West Coast semi-bleached kraft and Magnefite pulps. The table shows this comparison.

Table 33 Comparison of Organocell, semi-bleached kraft and Magnefite pulps

	Organocell	West coast semi-bleached kraft	Magnefite
NaOH %	20	20	15
Tensile m	7900	8500	6300
Burst kPa	350	470	320
Tear mN.m/m	1000	1100	810
Fold	730	1000	530

The degree of refining was not stated nor was the wood species identified. The levels suggest that the refining is to a CSF of 400 to 500 ml. Since the pulp is from the west coast it may contain Douglas Fir. The latter is a high tear - low tensile wood species and is not normally used for printing grades. The west coast fibre properties in the table are superior to those of Organocell for tensile (7.6%), burst (34%), tear (10%), and fold (37%) which suggests a healthy competitive edge to the West Coast pulp.

Dahlmann reports that a trial run of bleached Organocell pine pulp was successfully used as a reinforcement pulp in a 70 gsm grade. The trial was made on a high-speed paper machine at MD Papier GmbH without any runnability problems over a period of one shift. This was probably a coated printing and writing paper grade, and is a fairly heavy paper. Normally Northern Canadian kraft pulps are used for lighter weight grades than that made during the trial. The basis weight for magazine type papers is usually under 60 gsm and as low as 45 gsm. According to our market information MD produces coated printing and writing papers at a basis weight as low as 42 gsm.

For very low weight papers, strong Northern Canadian kraft pulps are used as reinforcing fibre to carry the coating. It would appear that the reported strength level of Organocell pulp would have difficulty meeting these demands.

It should be noted that intensive research on Organocell pulp has continued since 1977. After 13 years of research, Dahlmann indicates that "work needs to be done to fully understand the interactions of all operation parameters on pulp properties".

This demonstrates the difficulty in replacing kraft pulp with a competitive product even with the support of both government and industry, and with a clear objective identified.

7 ALTERNATIVE TECHNOLOGY TRAINS

Combinations of the effluent discharge technologies discussed in the foregoing chapters were assembled into several alternative "technology trains" for calculation of costs and improvements in effluent quality. These have been selected for each sub-sector of the industry, on the basis discussed on page 53. The use of the term "technology train" to describe a group of effluent discharge control technologies is based on the notion of connecting suitable and compatible processes together. **It does not imply that if a mill implements one train that the next logical step is to implement the next higher numbered train.** This would result in considerable waste of resources in some cases. The "trains" are merely technology options that apply for each sector.

In all cases, good operational management practices, as discussed on page 223, are an essential part of any effluent discharge control system. They are not included in the technology trains explicitly, but operating cost estimates include sufficient staff to manage all systems in an environmentally effective manner.

In addition to the essential criteria for selection of technology trains discussed on page 55, the authors considered the likelihood of any technology being adopted. They also avoided selecting trains incorporating very similar technologies, or weak technologies. If a technology is not included, it is not intended to mean that it is totally unsuitable. Site specific conditions, innovative application methods, and new developments may make a weak technology perform effectively .

7.1 Kraft Sub-sector

It is assumed that all kraft mills will have to reduce AOX below 2.5 kg/tonne pulp, and to install secondary effluent treatment, due to various pressures from public, Ontario and Federal regulatory requirements, and from customers. Therefore, all technology trains evaluated include the necessary equipment for this.

In the case of kraft pulp mills, there are so many alternative technologies available, that an almost infinite number of combinations could be conceived. The terms of reference of this report required five alternative trains be evaluated. Budget and time constraints prevent evaluating all possibilities, but applicable technology has been reviewed in foregoing chapters. Both of the candidate technologies for lowering the Kappa number of pulp entering the bleach plant are included, since it is considered that the comparison is valuable. The lowest cost of the five trains selected would reduce effluent discharges to below the levels normal in most western Canadian, US and Scandinavia mills; while the most expensive corresponds to retrofitting the most advanced technology available to Ontario mills, and could reduce effluent discharges to the lowest in the world.

All potential technology trains considered include elimination of hypochlorite bleaching stages to reduce chloroform discharges, in addition to the reductions that result from the substitution of molecular chlorine by chlorine dioxide and non-chlorine bleaching agents.

The starting point for effluent reduction at source for all technology trains in kraft pulp mills is a good quality chip supply. This requires chips that are processed with modern thickness screening equipment with over-thick chips reprocessed in a chip slicer. Although the upgraded chip screening system has a positive impact on effluent quality, its principal justification is that it is a prerequisite for a top performing pulping operation, and has a payback from reduced operating costs. The authors have considered that mills with sub-standard chip preparation systems can justify upgrading primarily on economic grounds. There are no allowances in the estimates for chip preparation.

Well operated batch or continuous digesters are assumed for technology trains K1 and K2. Oxygen delignification is part of technology train K3 with the main impact on the kraft system being a 4.4% increase in solids to the recovery boiler, which would represent a 3.3% increase in heat input. Train K4 involves application of extended cooking to the currently proven limit. To attain this, the only technically proven approach for which reliable cost estimates can be calculated is to replace the existing digesters with a continuous digester. The increase in solids to the recovery boiler will be approximately 3%.

Technology train K5 combines K3 and K4 with both oxygen delignification and digester extended delignification. There would be a significant drop in bleached yield, from 40.0% to 37.6%, with a corresponding increase in wood consumption and an increase in steam production. These changes represent a cost increase of approximately $13.00/ADt, a 15% increase in solids to the recovery boiler, and a 16% increase in heat input.

There are a number of options in selecting the degree of delignification in the digester and in the oxygen delignification system. Those selected for the calculations were chosen on the basis of improving the effluent characteristics as much as possible. A more modest degree of delignification in the pre-bleaching stage would realize a substantial improvement in cost with very little increase in organochlorine discharge.

7.1.1 Train K1

This represents the simplest way of complying with the most demanding current Ontario and probable Federal requirements on BOD TSS, Toxicity, AOX, PCDD/PCDFs (dioxins and furans), and will reduce discharges of virtually all of the substances on the EMPPL list substantially.

Internal spill control

Where brown stock washing losses exceed 10 kg saltcake/tonne pulp, install one additional washing stage. If losses exceed 25 kg/tonne, replace washing system (assume belt washer for cost purposes)

Sufficiently high chlorine dioxide substitution to reduce emissions of 2,3,7,8 TCDD and TCDF below detection levels[65]

ASB (or AST where space constraints prevent ASB). Systems include emergency spill containment.

7.1.2 Train K2

Similar to train K1, but with elimination of molecular chlorine. Corresponds to the best attainable improvement in effluent quality by internal "reduction at source" measures without modifying the Kappa number entering the bleach plant. Any hypochlorite bleaching stages would be eliminated, with additional chlorine dioxide bleaching equipment installed as appropriate.

Internal spill control

Convert bleach plant to D E_o D ED sequence

Where brown stock washing losses exceed 10 kg saltcake/tonne pulp, install one additional washing stage. If losses exceed 25 kg/tonne, replace washing system (assumed belt washer for cost purposes)

ASB (or AST where space constraints prevent ASB). Systems include emergency spill containment.

7.1.3 Train K3

Similar to train K2, but with oxygen delignification to reduce the Kappa number of the pulp entering the bleaching process.

Internal spill control

Oxygen delignification (medium consistency, as installed in many mills 1980-1991)

Convert bleach plant to O_{WW} D E_O D E D sequence [66]

Where brown stock washing losses exceed 10 kg saltcake/tonne pulp, install one additional washing stage. If losses exceed 25 kg/tonne, replace washing system (assumed belt washer for cost purposes)

ASB (or AST where space constraints prevent an ASB)

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[65] *Considered as 10 pico grams/litre TEQ for the purposes of this report.*

[66] *WW refers to two stage washing.*

7.1.4 Train K4

Similar to train K3, but including extended cooking instead of oxygen delignification. Results are similar to those attainable with train K3.

Internal spill control
Extended cooking (requires new digesters)
Convert bleach plant to D E_O D ED sequence
Where brown stock washing losses exceed 10 kg saltcake/tonne pulp, install one additional washing stage. If losses exceed 25 kg/tonne, replace washing system (assumed belt washer for cost purposes)
ASB (or AST where space constraints prevent an ASB)

7.1.5 Train K5

Combination of trains K3 and K4. This would represent the most effective effluent control attainable by demonstrated technology.

Internal spill control
Extended cooking (MCC or RDH as appropriate)
Convert bleach plant to OO_{WW} D E_O D sequence[67]
Where brown stock washing losses exceed 10 kg saltcake/tonne pulp, install one additional washing stage. If losses exceed 25 kg/tonne, replace washing system (assumed belt washer for cost purposes)
Activated sludge secondary treatment system

The oxygen delignification system includes two stages, because this is currently considered the state-of-the-art. A major manufacturer advised that the capital cost is very similar to a single stage, and perhaps slightly lower, since the two pressure vessels required can often be shop fabricated, whereas a single stage would require more expensive field fabrication.

7.1.6 Exceptional kraft mills

The foregoing trains cannot be applied as stated to the Domtar mill at Redrock.

The Domtar mill bleaches only about 60 tonnes/day pulp, and only to the semi-bleach status required for newsprint manufacture, whereas all the other Ontario kraft mills bleach to at least the 88 ISO brightness required for integrated fine paper making or for market pulp. It is technically feasible to apply trains K1 and K2, although the cost per tonne pulp is high, as indicated in the cost summary tables in Chapter 8. While trains K3, K4 and K5 could, in principle, be applied, there is no demonstrated experience with equipment for such small pulp production rates, and the equipment manufacturers cannot readily indicate prices for such small, non-standard equipment. In any event, it is obvious that the economies of scale would be so far against such an installation that it would be a waste of resources to attempt the analysis.

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[67] *Notice that this bleach sequence would render the former E_2 and D_2 washers unnecessary in most mills, so they could perhaps be used for post-oxygen washing.*

However, the very low brightness required for newsprint grades suggests that the Lignox process, described on page 234 may be applicable. The history of this process in the Aspa mill leads the authors to conclude that it has proven its ability to produce kraft pulp sufficiently bright for newsprint (67 to 70 ISO). The cost estimates are based on the authors' estimates of the chemicals required.

The E.B. Eddy mill already uses high chlorine dioxide substitution and neither TCDD nor TCDF were detected in its effluent during the 1990 monitoring program. The mill is operating at a level equivalent to train K3.

The mill has retro-fitted extended cooking capabilities, but these are not capable of lowering the Kappa number to the state-of-the-art levels that a new digester can attain, so the cost estimates include the latter for trains K4 and K5.

7.1.7 Reduction of kraft mill effluent flows

The effluent flows in the nine mills in the kraft sub-sector ranged from approximately 75 to 170 m^3/tonne in 1990. Historically, there has been a strong incentive for Canadian mills NOT to reduce effluent flows, since the Federal and Provincial requirements for non-toxic effluent were based on concentration of toxic substances in the effluent, and at various times concentration standards have been applied for other substances, including, for example, 50 mg/L for BOD and TSS in Ontario, and 0.03 mg/L for Phosphorus discharges from the Paperboard Industries mill at Trenton.

There have never been any regulations that directly encouraged low effluent flows in Canada, and the authors are not aware of any in other parts of the world. Where raw water is expensive or unavailable, one finds relatively low effluent flows. One example is the Glatfelter mill discussed in Appendix C, which uses 65 m^3/tonne to manufacture bleached kraft pulp and a wide variety of speciality fine paper grades in an integrated paper mill with eight machines. The Mönsterås mill in Sweden (also discussed in Appendix C) uses 50 m^3/tonne to manufacture market pulp. A recent NCASI study (Borton 1991) mentions a market kraft mill using 57 m^3/tonne and an integrated kraft/fine paper mill using 47 m^3/tonne.

It is not unusual for mills to institute water conservation programs prior to installing effluent treatment systems, in the interests of lowering capital costs. In the authors' experience, the economic optimum flow is somewhat under 100 m^3/tonne if an activated sludge system is being installed, and substantial flow reduction is rarely economically justifiable when an ASB is the effluent treatment process. Where BAT effluent quality is desired and biological effluent treatment is being used, flows would have to be reduced to the lowest levels proven to be technically feasible. While this will reduce effluent treatment costs somewhat, the net effect of reducing flows would be to raise capital costs and increase equipment maintenance costs.

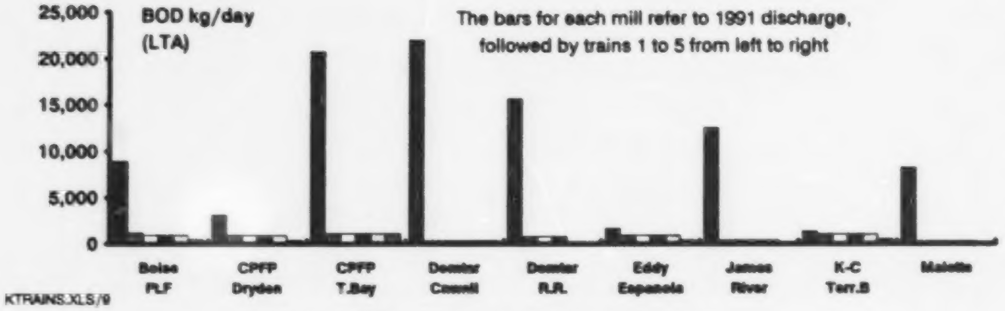
All of the above technology trains would achieve some reduction in effluent flow, and the cost estimates include allowances for reduction of effluent flows to 50 m^3/tonne. The allowance varies according to the size of the mill, the current flow and whether other process modifications in the same technology train would reduce flows. For example, where a new brown stock washing system is required and included, it would reduce effluent flows substantially by itself.

7.1.8 Reduction of BOD and TSS components

The discharges of BOD and TSS that result from the application of each alternative technology train to each kraft mill are shown in Figures 43 and 44.[66]

It is characteristic of external treatment systems for pulp and paper mill wastes that attainable effluent BOD and TSS are related to "floor" effluent concentrations rather than to proportional reduction of loads, or to the untreated effluent BOD and TSS concentrations. Minimum attainable discharge rates for BOD and TSS are therefore closely related to water usage. Hence, water conservation programs are key tools in attaining very low discharges of TSS and BOD.

Trains K1 to K4 include ASB secondary treatment systems where space permits on the mill site, otherwise AST is used. Train K5 incorporates activated sludge secondary treatment, so will have lower BOD and TSS discharges. In the cases of Domtar at Cornwall and CPFP at Thunder Bay, the AST process was used for all trains, since these mill sites lack sufficient space for an ASB. Trains K2 to K4 all presume the same 50 m^3/tonne process effluent flow and secondary treatment technology (ASB), so will therefore have the same BOD and TSS production based discharge loads (kg/t). Train K1 incorporates reduction of effluent flows to 60 m^3/tonne.



Trains K4 and K5 are not applicable at Domtar, Redrock.
Refer to numerical presentation of data in Chapter 8 for values too low to read on this scale.

Figure 43 BOD discharges for kraft sub-sector technology trains

The "1991" discharges shown for BOD and TSS represent the discharge conditions expected after any effluent discharge control systems which started construction prior to May 1991 are operational. They correspond to the basis for capital and operating cost estimates in this report.

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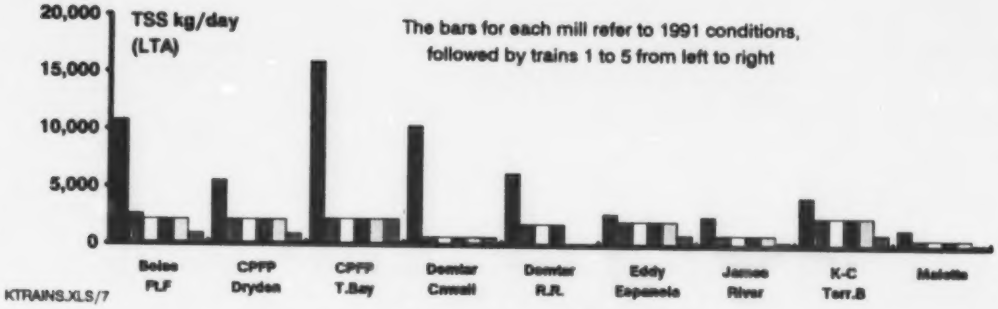
[66] *The effluent data are also shown numerically in Chapter 8 for all sub-sectors.*



Trains K4 and K5 are not applicable at Domtar, Redrock.

Figure 44 TSS discharges for kraft sub-sector technology trains

7.1.9 Reduction of COD

The reduction in BOD for the different trains is the same for any one mill because of the characteristic floor concentrations available with biological treatment. However, there is a major difference in the COD discharged between the different trains, because the internal measures for discharge prevention at source which are incorporated into some trains are much more effective in reducing COD than BOD.

Table 34, based on Table 21, shows the results of a detailed mass balance of all the trains for a generic bleached market kraft pulp mill. It is assumed that the COD consists of dissolved organics from the mill, and condensates. TSS is not included because they are insignificant and will remain the same in all trains. The table shows that the COD removal is almost doubled from train K1 (35 kg/ADt removed) to train K5 (60 kg/ADt removed). The COD/BOD and COD/AOX ratios of discharges are much improved by the internal measures in train K3, K4 and K5 (oxygen delignification and extended cooking) rather than by the lower capital cost option of adopting 100% chlorine dioxide substitution and biological treatment. The biological treatment plant for the latter three trains is considerably smaller than for train K1 and K2.

Table 34 Calculation of COD mass balance for generic market bleached kraft pulp mill

kg/tonne	Base case	70% sub	100% sub	Oxygen delig.	MCC	Oxydelig + MCC
Technology train ----------->	----	K1	K2	K3	K4	K5
Dissolved organics from fibre line	88	88	88	64	55	57
COD in dissolved organics	105	105	105	76	65	68
COD in condensates	13	13	13	13	13	13
Total untreated COD	118	118	118	89	78	81
COD removed in biotreat	0	35	35	25	22	23
COD discharged	118	83	83	64	57	58
COD removed from base case	0	35	35	55	62	60

7.1.10 Reduction of AOX components

Ability to reduce AOX discharges was one of the major criteria in selecting the technology for the technology trains for the kraft sub-sector, since regulators worldwide are particularly in favour of regulating this parameter. The 1990 AOX discharges from the Ontario mills are presented in the reports on the MISA sampling program (MISA 1991). These data are already somewhat obsolete, since several mills implemented measures to reduce AOX discharges in late 1990 and early 1991. The authors estimated the AOX discharge rates for April 1991, to serve as the basis for the cost estimates discussed in Chapter 8. These data are shown in Figure 45, along with the predicted discharges for the various technology trains.

Train K1 will substantially eliminate the bioaccumulative fraction of AOX (approximately 0.1% of the AOX from conventional chlorine bleaching). There will still be weak chronic-toxic effects of the effluent after this train, suspected to be caused by non-chlorinated wood extractives (Folke 1991). Train K2 will further reduce AOX by about 0.7 kg/ADt but will not eliminate any of the compounds that cause these weak chronic-toxic effects (except that the chip upgrading would be somewhat beneficial in this respect) (MFG 1991). Trains K3 and K4 will be more effective in reducing weak chronic-toxic effects due to the incorporation of oxygen delignification or extended cooking to reduce the amounts of wood extractives in the effluent. Trains K2, K3, K4 and K5 all use 100% chlorine dioxide substitution. The additional AOX reduction that results from this total elimination of molecular chlorine when compared to that achieved by train K1 is primarily of low-chlorinated AOX of the types that are synthesized in natural aquatic ecosystems (Grimvall 1991).

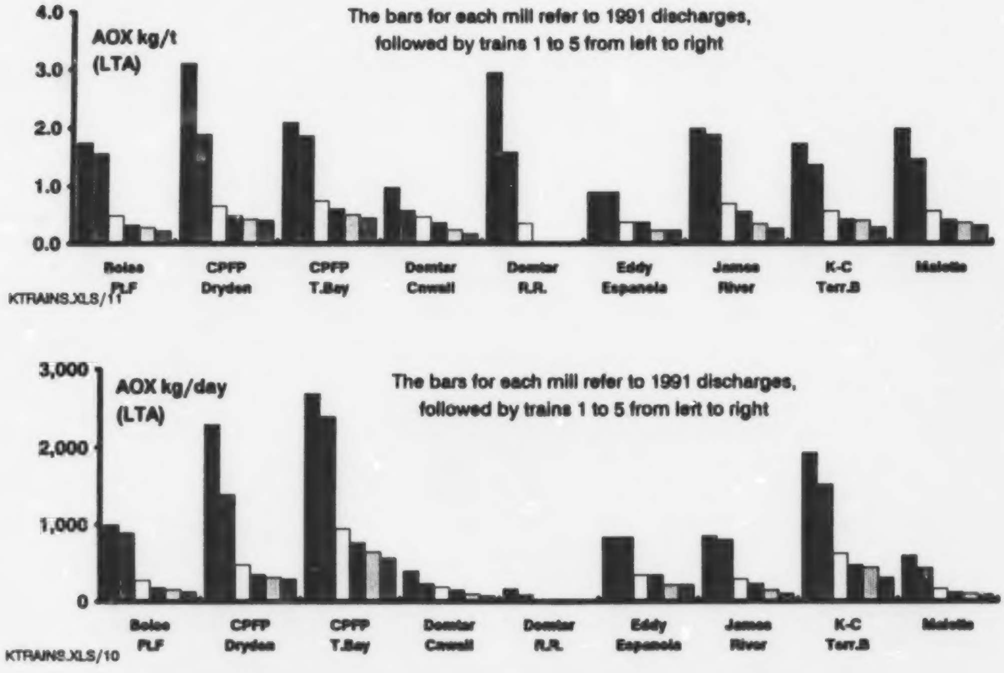


Figure 45 AOX discharges for kraft sub-sector technology trains

The "1991" discharges shown for AOX represent the discharge conditions expected after the improved bleaching systems at several mills on which construction commenced prior to May 1991, and the AST system at Canadian Pacific Forest Products Ltd., Thunder Bay are operational. They correspond to the basis for capital and operating cost estimates in this report.

COD/AOX or DOC/AOX ratios

The COD/AOX ratio reflects the chlorination rate of organic materials as discussed on page 115. Train K1 is expected to result in a COD/AOX ratio around 20, K2 will probably have a ratio around 30 and trains K3 to K5 will have a ratio around 40. Therefore the AOX resulting from trains K3 to K5 has a closer resemblance to naturally synthesized AOX than the AOX discharged by mills using trains K1 and K2.

7.1.11 Reduction of chlorophenols

Chlorophenols cannot be considered as a homogeneous group. Lower chlorinated phenols, i.e. with a single or perhaps two chlorine atoms on the ring are biodegradable and less lipophilic than chlorophenols with three or more chlorine atoms on the ring. Bleach plants using high amounts of molecular chlorine can form a range of polychlorinated phenols (PoCPs). Among these are tetrachlorinated guaiacol and catechol, 2,4,6-trichlorophenol and other trichlorinated phenolics and guaiacols of catecholic origin. When the chlorine multiple of the C/D stage is lowered, the mono and dichlorinated are the principal phenols formed. All chlorophenols can be reduced by biological treatment. Mono and dichlorinated phenolics by degradation, polychlorinated ones by association with suspended solids removed during the process. (The fate of the latter will depend on the subsequent sludge handling).

The MISA program included the analyses of 2,4-dichlorophenol and 2,4,6-trichlorophenol, but none of the other chlorophenols of bleach plant origin. 2,4-dichlorophenol will be reduced below 0.5 g/ADt by all trains because of the biological treatment, whereas 2,4,5-trichlorophenols may be present in amounts around 0.5 g/ADt after biological treatment in trains K1 and K2. Trains K3 to K5 are marginally better in reducing 2,4,6-trichlorophenol with amounts certainly being lower than 0.5 g/ADt. Treated discharges of 2,4,6-trichlorophenol may be lower than 0.1 mg/ADt, but there are no data available to substantiate this for a bleach plant applying 100% chlorine dioxide substitution.

7.1.12 Reduction of chloroform

Chloroform is primarily formed by the alkaline haloform reaction in the hypochlorite stage of the bleach plant, if any. In mills using hypo bleach, amounts from 200 to 1000 grams chloroform/ADt in untreated effluent have been reported. Elimination of the H-stage reduces the amount of chloroform in untreated effluent by a factor of about 100.

Chloroform is not aerobically degradable, but aerobic biological treatment will reduce the concentration, a factor of 10 to 100 depending on the concentration in the untreated effluents, by purging to the air. Internal process modifications to reduce the formation of chloroform, such as elimination of the H-stage (as in trains K2-K5), and the reduction of chloroform precursors as resulting from trains K3 to K5 is the only way to reduce environmental exposure to chloroform from bleach plants. These will bring chloroform down to levels below 0.1 mg/L in treated effluents without stripping significant amounts to the atmosphere.

7.1.13 Reduction of resin acids

Prediction of the extent of reduction of resin acid discharges attainable by the alternative technology trains is complicated by a lack of general data. The 1990 MISA monitoring program provides some information, as does the detailed effluent characterization of effluents at the Mönsterås mill discussed in Appendix C.

Both of the Ontario kraft mills which have biological treatment systems approaching BAT quality effluent with respect to BOD and TSS, discharge an average of 3 grams total resin acids per tonne pulp, with a maximum value of 12.3 g/tonne for one sample in the first six months of 1990.

All the kraft technology trains include effluent treatment systems designed to criteria similar to the Terrace Bay installation, so they can be expected to reduce the resin acid content similarly. There are insufficient data to predict daily/monthly/annual values. Trains K3, K4 and K5 would recycle and burn approximately half of the 100 to 200 g/tonne resin acids normally discharged from a mill with conventional pre-bleaching processes. This could be expected to reduce the final resin acid content somewhat, but there are insufficient data for quantitative predictions. The Espanola mill, which uses oxygen delignification, discharges essentially the same quantities of resin acids as the Terrace Bay mill which has conventional bleaching but a more efficient ASB.

7.1.14 Reductions in sub-lethal toxicity

Resin acids are components of black liquor, especially soap. They are frequently reported in the bleach plant E_1 stage, because the lipophilic lignin that they are associated with, in the brown stock, is made more soluble by the action of chlorine compounds in the first C/D stage. The subsequent treatment in alkali transforms resin acids into their ionized form so that they can be washed out. Resin acids are tracers of black liquor solubles in untreated effluents. Reducing resin acids in such effluents, implies reduction of the overall amount of black liquor solubles Part of these solubles resist biological degradation in the biological treatment plants, and are the cause of weak chronic toxic effects in treated effluents. Therefore, trains K3 to K5 involving internal measures to reduce soluble matter by returning a greater fraction of the black liquor to the recovery system can be expected to reduce non-biodegradable black liquor solubles in the treated effluent.

Trains K3 and K5 are expected to be more effective in reducing weak chronic toxic effects associated with persistent compounds in kraft black liquor (MFG 1991). According to Borton (1991) the concentrations of effluents from mills using oxygen delignification which caused a 25% reduction in the numbers of young produced in receiving waters were three times higher than for conventional mills. This indicates that trains K3 and K5 can be expected to be more effective in reducing the effects of mill effluents on reproduction, than trains K1 and K2 in this respect[69]. Neither MFG nor Borton have data to comment on the effects of technology such as train K4 which uses extended cooking technology to remove similar quantities of black liquor solids from the untreated effluents as the oxygen delignification system in train K3. One would expect the effluent from train K4 to be similar to K3 with respect to persistent compounds, but there no data to support or contest such a conclusion.

7.2 Sulphite Mechanical Sub-sector

The variety of in-plant technology available for effluent discharge prevention at source for this type of mill is quite restricted relative to the kraft mills discussed previously. The technology of reducing effluent flows in this type of mill is well known, but has generally not been implemented in Ontario, presumably for reasons similar to those discussed on page 245 for the kraft sub-sector.

Envirocon (1977) indicated that significant reductions in BOD and TSS discharges could be expected to accompany reductions in flows of process effluents in newsprint mills. However, there does not appear to have been any more recent publications on this subject.

The Envirocon report mentioned one mill which operated with a process effluent flow of approximately 55 m^3/tonne. The Hylte mill discussed in Appendix C operates with 15 m^3/tonne of effluent. The authors considered the practicality of reducing effluent flows to this level in Ontario, but feel that the time scale of the current MISA program would limit the attainable flows to about 50 m^3/tonne. In any event, the only significance of effluent flow is to arrive at a definition of an attainable effluent discharge for those parameters that reach a floor concentration with proven external treatment technology.

With considerable reservation, the authors decided not to include the ASB process in the following BAT technology trains, for the mills as they exist to-day, because of a lack of full scale demonstrated operation in cold climates. The very few mills similar to those in Ontario's sulphite/mechanical sub-sector which have been required to install secondary treatment use the AST process. Most newsprint mills in Canada and the Northern US which have secondary treatment abandoned the high-yield sulphite operations and either purchase kraft pulp or produce a 100% TMP sheet. ASB operations in somewhat similar mills at the Finlay Forest Mill in MacKenzie, BC and the Abitibi-Price mill in Stephenville, Newfoundland demonstrate that an ASB could perhaps be used successfully, so the authors consider that it should not be excluded for evaluation by mills and regulators.

7.2.1 Train S1

Install an activated sludge treatment system (AST) to treat all wastes. Modifications to reduce effluent flows internally to 50 m^3/tonne, or lower, where appropriate.

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[69] *Borton's work reflects relatively small receiving water flows and short term effects only.*

7.2.2 Train S2

As train S1 above, but with the addition of a granular filter to reduce TSS discharges, thus reducing the discharges of the pollutants that tend to travel with the solid fraction of the effluent stream.

7.2.3 Train S3

As train S1 above, but with the addition of chemically-aided coagulation to reduce suspended solids and phosphate discharges. This process will also reduce heavy metals in the effluent stream, but will concentrate them in the sludge.

The 1990 effluent discharges and the expected results of applying each of these trains to the mills in the sub-sector are shown in Figure 46 and 47.[70]

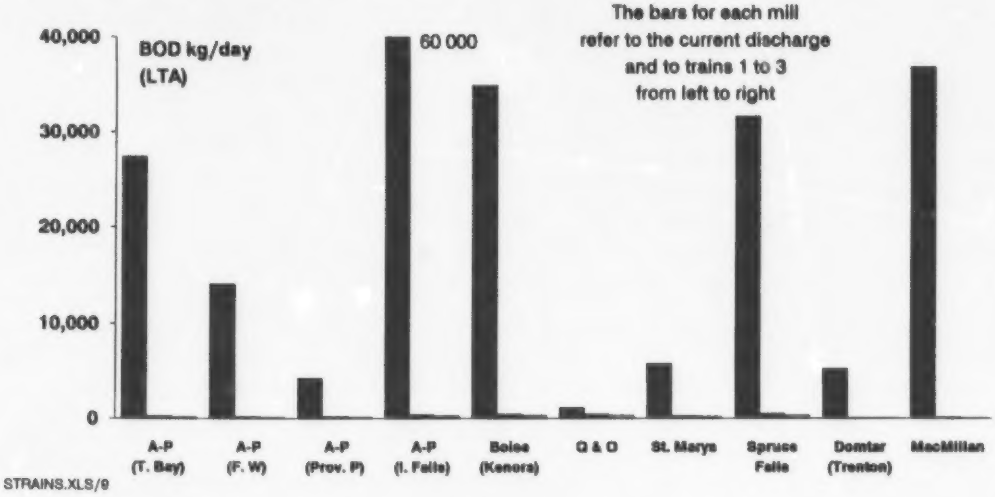

Figure 46 BOD discharges for sulphite/mechanical and corrugating sector technology trains

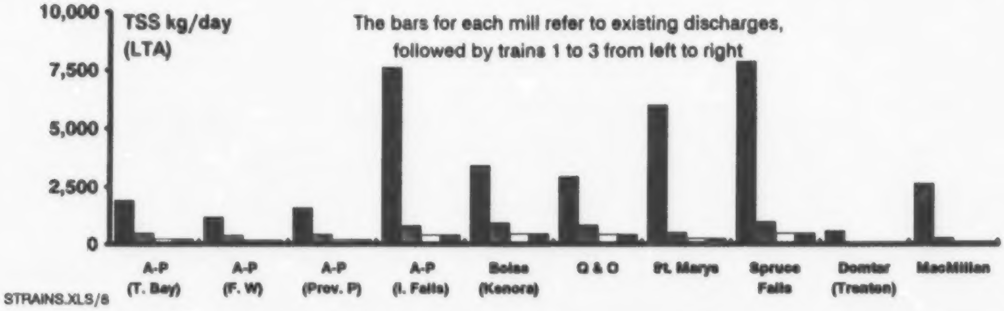

Figure 47 TSS discharges for sulphite/mechanical and corrugating sector technology trains

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[70] *The effluent data are also shown numerically in Chapter 8 for all sub-sectors.*

7.2.4 Alternative technology for the sulphite/mechanical sector

Replace the complete pulping facility with a new TMP mill. The newsprint and/or speciality paper machines would operate as at present. A new TMP mill of the size range that would generally be required, would cost approximately $100 to $150 million.

The pulp mill would produce thermomechanical pulp, which would be the only furnish for the paper machines in the newsprint mills, apart from any deinked stock used. Mills producing groundwood specialities, as at St. Marys, would continue to use some purchased chemical pulp.

Install an ASB effluent treatment system (or AST where space constraints prevent ASB). The costs for this would be in the order of half those for treatment of the mill effluents as they existed in 1990.

This alternative is effectively a replacement of a major part of the mill, and could be considered outside the scope of this report. However, **this is the approach taken by most mills elsewhere who were faced with the high costs of treating sulphite waste liquor**.

7.3 Corrugating Sub-sector

There are only two mills in this sub-sector, and a limited number of relevant technologies available. In many ways they parallel the possibilities for the sulphite/mechanical sub-sector.

7.3.1 Train C1

Install an activated sludge treatment system (AST) to treat all wastes. Install modifications to reduce effluent flow at source as appropriate.

7.3.2 Train C2

As train C1 above, but with the addition of a granular filter to reduce suspended solids discharges, thus reducing the discharges of the pollutants that tend to travel with the solid fraction of the effluent stream.

7.3.3 Train C3

As train C1 above, but with the addition of chemically-aided coagulation to reduce suspended solids and phosphate discharges. This process will also reduce heavy metals in the effluent stream, but will concentrate them in the sludge.

The 1990 effluent discharges and the expected results of applying each of the foregoing technology trains to the mills in the sub-sector are shown in Figures 46 and 47, (page 252).

7.3.4 Other options for corrugating mills

Liquor incineration/chemical recovery

Install a waste liquor incineration system to minimize the losses of organics to the effluent. This would include pulp washing, spill control and evaporation of the waste liquor. The pulping process would be converted to a non-sulphur variation, so that the ash recovered from the boiler would be either reusable or marketable in competition with caustic.

The paper machine white water system would be integrated with the pulp mill, so that the only effluent from the paper mill would be slightly contaminated vacuum pump seal water.

This approach has been used in several US mills and at Cabano, Quebec. However the trend towards increasing use of waste paper makes further installations less likely. There are two Ontario mills that could potentially use this process. One is Domtar at Trenton, where the waste liquor is presently recovered and used as road binder, so that incineration would have little effect on the effluent discharges. The other is at Sturgeon Falls, but this mill has recently installed an anaerobic treatment system as an alternate. In view of the low possibility of this process modification being installed, or even being environmentally useful, in Ontario, cost estimates were not prepared.

Waste paper furnish

Eliminate chemical pulping and replace with 100% waste paper furnish, with closed cycle operation. Products could then include linerboard and other packaging materials. This is a plausible option, which has been undertaken by other former corrugating medium mills. The authors found it impracticable to prepare credible estimates of cost, but it is clear that it is not unreasonable to assume that it could be economically feasible. The technologies required to convert a board mill to closed cycle, zero effluent operation do not require excessive quantities of energy or create unacceptable quantities of solid waste. Refer to the discussion on the Grenaa mill in Appendix C.

One mill operator expressed concerns that the solid waste disposal problems could be insurmountable. There is no doubt that it is extremely difficult to predict costs of solid waste disposal for new landfill sites in Ontario, due to the uncertainty as to the expectations of the Ministry and the public.

7.4 Deinking/Board/Fine Paper/Tissue Sub-sector

The opportunities for effluent reduction at source in these mills are generally limited to improving white water management. Some mills in this sector have already done so to a remarkable degree, such as the Kimberly-Clark mill at Huntsville, but it is not technically feasible to attain an equal degree of recycle in all mills in this sub-sector.

The alternative technology trains all include effluent flow reduction to under 50 m^3/tonne product by internal process modifications, and various alternative forms of external treatment.

7.4.1 Train F1

Install an aerated stabilization basin (ASB), where appropriate. The Kimberly-Clark mills at St. Catharines and at Huntsville already discharge effluent of better quality than attainable with an ASB. Domtar at St. Catharines, Noranda at Thorold and E.B. Eddy at Ottawa all lack the necessary space, and being urban locations it would be impractical to install an ASB.

7.4.2 Train F2

Install an activated sludge treatment system. The Kimberly-Clark mills at St. Catharines and at Huntsville already discharge effluent of equal or better quality than would be attainable with an AST system.

7.4.3 Train F3

Install an AST with tertiary treatment of effluent by granular filtration.

7.4.4 Train F4

Install an AST with tertiary treatment of effluent by coagulation.

The 1990 effluent discharges and the expected results of applying each of the foregoing technology trains to the mills in the sub-sector are shown in Figures 48 and 49. The quantities of pollutants discharged by the Kimberly-Clark Canada mill at Huntsville are too low to be visible on the scale of the graph. They will not change, since none of the BAT technology trains would be applicable to that mill.

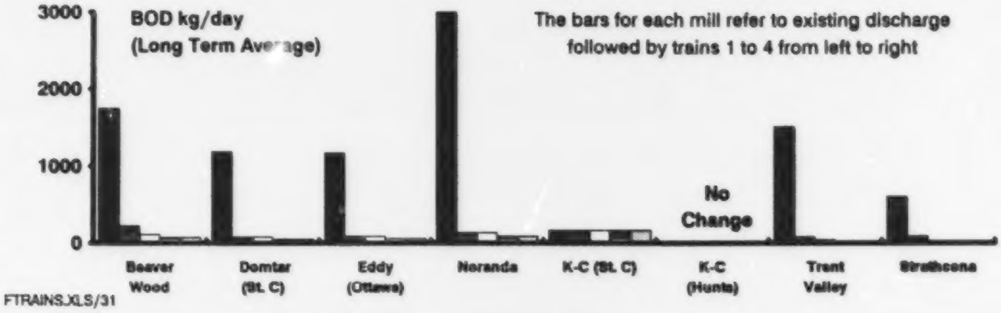

Figure 48 BOD discharges from deinking/board/fine papers/tissue sub-sector technology trains

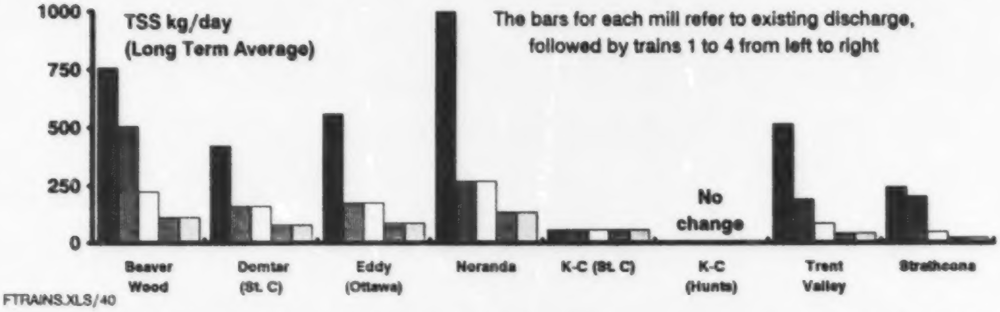

Figure 49 TSS discharges from deinking/board/fine papers/tissue sub-sector technology trains

7.4.5 Other options

Complete system closure. This is potentially applicable to the Paperboard Industries mill at Trenton and the Beaver Wood Fibre mill at Thorold only.

This is a plausible option, which has been undertaken by various board mills. The authors found it impracticable to prepare credible estimates of the costs for the Ontario mills, since this would require several weeks of engineering time to calculate the mass and energy balances required. However, it is clear that it is not unreasonable to assume that it could be economically feasible, since an increasing number of mills do so. The technologies required to convert a board mill to closed cycle, zero effluent operation do not require excessive quantities of energy or create unacceptable quantities of solid waste. Generally, it is technically simpler to modify mills such as these which do not manufacture pulp on site than in the case of mills such as Green Bay (discussed previously on page 185 and 226) which manufactured pulp. Refer also to the example of the Grenaa mill discussed in Appendix C.

8 COSTS of APPLICATION of TECHNOLOGY TRAINS

Capital and operating costs were estimated for implementation of each of the alternative technology trains described in Chapter 7, for each of the 27 mills within the scope of this project. Capital costs range from zero, for the Kimberly-Clark mills at Huntsville and St. Catharines, to approximately $140 million for CPFP at Thunder Bay. Direct annual operating costs would range up to almost $5 million, while one mill could save up to $8 million.

In all cases these costs are in addition to environmental protection costs incurred by the mills prior to April 1991.

The individual cost estimates are presented in tabular and graphical form at the end of this chapter. In a few cases, the costs are shown as zero because the mill effluent discharges are already below the levels considered to be attainable by the technology train concerned In such cases, the mills have incurred prior expenditures which are not considered in this report.

The cost calculations discussed below are all based on the assumption that the **selling price of the product will not be affected by the changes to the mill process undertaken to improve the effluent quality**. In the case of the non-kraft mills, the authors are confident that this is valid, since the alternative technology trains for improving effluent quality are based primarily on external treatment. However, in the case of kraft mills, the situation is more complicated, since some of the technology trains involve substantial modifications to almost all parts of the pulp production and bleaching systems. All the technology selected for the alternative trains will allow production of pulps with substantially the same product quality as the current mills, but subtle differences will exist. It is impossible to predict the effects of these on the selling prices of the pulp. Off-specification pulp is commonly discounted by up to about $50/tonne, which could perhaps indicate the possible downside price fluctuation if some aspect of quality is unsatisfactory.

Conversely, there is no doubt the high chlorine dioxide substitution ratios and extended cooking technology involved in the technology trains will improve pulp cleanliness and other qualities. This may assist the mills which undertake the process modifications to sell otherwise unmarketable pulp in the current soft market, or to raise prices, but there is no rational way of predicting the extent of this, or whether it will actually take place. The pressures by environmental organizations against chlorine bleached products may facilitate marketing pulp from mills which install the more advanced technology trains described in Chapter 7, but any predictions of the extent of this would be purely speculative. Some analysts have stated that customers cannot obtain sufficient "chlorine-free" pulp, without specifying whether they mean molecular chlorine free or chlorine compound free. On the other hand, as discussed on page 230 the only mill manufacturing chlorine-compound-free market kraft pulp is unable to sell more that 20% of its production capacity. Comparisons of the costs of the various alternative effluent control measures for kraft pulp mills must be considered in the perspective of the 1990 selling price having dropped from over $900/tonne to under $700/tonne from late 1989 until early 1991 (Mohr 1991).

8.1 Capital Costs

The capital costs for the various alternative technology trains that could be installed in each mill were calculated, considering all site-specific information available to the authors.

8.1.1 Basis for estimates

Capital costs were calculated for a range of capacities for each unit operation in standard effluent treatment systems, based on either the aerated stabilization basin, or on the activated sludge process described in Chapter 5, according to the site conditions and mill processes **Where it appeared likely that the installation of a submerged outfall would be required, allowances were included for its construction and maintenance.** Equations were developed for each unit operation that allowed the capital cost to be calculated from capacities selected by the authors, on the basis of effluent loads and site conditions.

Similar equations were developed for the process modifications for prevention of discharges at source, to the extent feasible. These were based primarily on the known costs of comparable projects, and capacity adjusted by the "six-tenths" rule, where the cost of similar facilities of differing capacities is assumed to vary with the six-tenths power of capacity. In some cases special allowances were made for known local difficulties.

Individual estimates were calculated for each mill, for each of the technology trains, in accordance with the criteria mentioned below. In all cases, one or more of the authors has first-hand knowledge of the mill site, and has visited it within the past three years. In some cases, drawings were obtained and/or telephone interviews were undertaken with Ministry of the Environment and/or company engineers who are familiar with the site, to clarify local conditions.

Equipment selection was generally based on the data presented in Appendices A and B of this report, the first six months of the 1990 MISA Monitoring Program, and on-site specific constraints, in accordance with normal engineering practice. However, where the authors have knowledge of major changes since that time, these were incorporated. In all cases, the costs are based on mills as they existed in April, 1991. **If a mill had already implemented the technology concerned, or achieved equivalent effluent quality, because of its inherent process and/or because of prior expenditure, it is shown as having zero cost.**

The necessary process equipment for discharge prevention at source, main effluent pipelines, pump stations, roads, aeration equipment (including power supply), secondary clarifiers, sludge thickeners, and reaction vessels were sized using conventional engineering practice, and costs were calculated for each. The estimated costs of all major elements include allowances for the related auxiliary equipment, such as controls, lighting, etc.

Various special allowances were allocated for manufacturing process modifications to reduce or eliminate discharges at source, where some changes were necessary to comply with the effluent quality target concerned, or were clearly desirable to reduce overall costs. It is likely that the optimum cost for many mills could be reduced slightly after a detailed engineering study to optimize the trade-offs between discharge prevention at source and external treatment, particularly where the effluent treatment project could be integrated with a mill modernization program.

Costs for each element were calculated for an average Ontario, rural location on the basis of the capacity of each element. Some special site allowances were added for piles, restricted locations, known high construction labour costs, etc. Engineering, owner's overheads, and contingency are included in all estimates for each individual item.

There are no allowances for the costs of acquisition of land. In most cases these costs will be minor, since the only type of installation used that would require significant areas would be ASB effluent treatment. This process has been assumed only where land is readily available and is remote from urban areas. Where the mill site is particularly restricted, allowances are included for pipelines and pumping systems to suitable sites for external effluent treatment.

This approach of calculating estimates for each mill was selected as the best way of estimating the total costs for each alternative technology train for each site. Such estimates can never be as reliable as those based on detailed engineering analysis, flowsheets, site layouts, soils studies and contractors' bid prices. Several capital cost estimates calculated on the basis of a very similar cost model (McCubbin 1990, Sprague 1991) were checked against independent estimates based on detailed studies undertaken by mill engineers or their consultants, and were found to be within 20% of the latter costs. It is the belief of the authors that the detailed site-by-site analysis is superior to the more widely used approach of relying on costs calculated on the basis of loads for generic effluent treatment processes. This latter approach was used successfully in the USEPA's well known development documents for effluent guidelines in the 1970s and 1980s. However, they were generally dealing with mills at a fairly uniform level of installation of environmental protection measures, and at a time when technology for effluent control at source was much simpler than is available for Ontario mills today.

In cases where effluent treatment costs are extremely high, it is quite likely that mill owners would prefer to modernize the mill to use a production process that discharges substantially lower quantities of pollutants. Such alternatives were not considered to be within the scope of this project.

8.2 Operating Costs

Operating costs were calculated for each of the capital installations described in the foregoing pages.

8.2.1 Basis for estimates

Costs of chemicals (chlorine dioxide, oxygen, lime, nutrients, polymer, etc.) maintenance, and power required were calculated for each mill, using the unit costs listed in Table 35.

Labour costs were taken from Statistics Canada (1990) data on actual average earnings in the industry, plus an allowance of 25% for fringe benefits. Laboratory technician time was calculated as double those rates to allow for equipment, consumed supplies, etc. Appropriate professional supervision and technical support were included at an assumed total cost to the mill owner of $50/hour. This assumes that a normal amount of external expertise would be retained each year for audits, assistance in resolving special problems etc. The amount of time allowed for professionals and technicians was varied somewhat according to the level of performance required and the complexity of the installation.

It was assumed that dewatered sludge can be disposed of at a fixed cost (Refer to Table 35). This maybe higher than the real cost where a mill can simply add the sludge to an existing hog fuel stream, but is considered a reasonable average for all cases.

The authors believe that the accuracy of the estimates of annual operating costs is probably better than +/-20%.

Table 35 Base unit costs for operating cost estimates

Item	Units	Cost
Ammonia	\$/kg NH_3	\$0.40
Anthraquinone	\$/kg	\$11.00
Caustic (ECU)	\$/kg	\$0.27
Caustic (non-ECU)	\$/kg	\$0.35
Chlorine dioxide	\$/kg	\$1.02
DTPA	\$/kg	\$1.40
Fertilizer for nutrient	\$/kg	\$0.37
Hydrogen peroxide	\$/kg	\$1.32
Hypo (available Cl_2)	\$/kg	\$0.32
Lime for neutralization	\$/kg CaO	\$0.09
Molecular chlorine	\$/kg	\$0.15
On-site oxygen	\$/kg	\$0.09
Oxygen by truck	\$/kg	\$0.16
Phosphoric acid	\$/kg H_3PO_4	\$1.03
Polymer for biosludge	\$/kg	\$10.50
Sulphuric Acid	\$/kg	\$0.13
Steam	\$/t	\$9.00
Power	\$/kWh	\$0.04
Softwood	\$/ODt	\$140.00
Hardwood	\$/ODt	\$105.00
Cost to company for each of the following services (Inc overhead, training, travel etc)		
Operators	\$/ hour	\$24.30
Technicians	\$/hour	\$53.00
Process engineer	\$/hour	\$80
Sludge disposal	\$/dry tonne	\$100
Days/yr at nominal production		355

In certain cases, where mill staff provided different local costs, these were used in calculations instead of the above data. The personnel costs include the cost of the appropriate indirect overheads such as laboratory equipment, travel to conferences and other expenses to maintain a high level of competence with normal staff turnover.

8.3 Costs for Kraft Sub-sector

The capital and operating costs for the mills in the kraft sub-sector are shown in Table 36 on the following pages, along with a brief summary of the predicted effluent characteristics.

The data shown were calculated for individual mills, and in some cases the effluent characteristics differ from the sector-wide data discussed elsewhere in this report. This is particularly true for AOX, since some mills will attain lower discharges that the sector as a whole for any particular technology, due to local advantages such as favourable wood.

The table also includes the principal elements of the data on effluent from each mill which were used for calculating the expected costs. This frequently differs from the data from the 1990 MISA monitoring program discussed in this report, because most of the kraft mills have modified the mill processes to reduce AOX, dioxins or other discharges after the 1990 program was substantially complete. In addition, CPFP shut down the sulphite mill, replaced a substantial quantity of groundwood pulp with TMP and commenced construction of an oxygen activated sludge treatment system at their Thunder Bay mill.

The costs vary widely, and there is no simple relationship between either capital or operating costs and existing effluent loadings. Within any one mill, the relationship between costs and final effluent discharge characteristics is usually extremely non-linear. In all but exceptional circumstances, additional expenditure can achieve less contaminated effluent. In some cases, operating costs can be reduced by increased investment, but in others the more sophisticated, high-capital-cost plants require higher operating expenditures than simpler installations.

Where operating costs are shown to be negative, it is usually because the installations involved would reduce chemical and energy costs sufficiently to offset other direct operating and maintenance costs.

Table 36 Predicted effluent characteristics and costs for the kraft sub-sector

		Boise Fort Frances	CPFP Dryden	CPFP Thunder Bay	Domtar Cornwall	Domtar Red Rock	Eddy Espanola	James River Marathon	K-C Terrace Bay	Malette Smth. Rock
Base case effluent data (1991, *refer to note***)**										
Production rate	t/day	970	965	2,290	726	819	943	425	1,110	297
Bleached product	t/day	573	735	1,279	412	57	943	425	1,110	297
Effluent flow	m³/day	77,276	91,707	173,931	126,049	95,187	98,577	61,888	95,122	50,664
TSS	kg/day	10,793	5,524	16,000	10,415	6,260	2,745	2,578	4,279	1,512
BOD	kg/day	9,000	3,132	20,793	22,053	15,716	1,689	12,564	1,408	8,310
AOX	kg/day	1,000	2,293	2,683	401	169	841	850	1,931	596
AOX	kg/t	1.7	3.1	2.1	1.	3.	0.9	2.	1.7	2.
Phosphorus	kg/day	136	181	117	43	21	55	40	49	19
TKN	kg/day	742	175	253	355	178	325	191	441	103
Train K1	*Eliminate detectable dioxins*									
Capital cost		$13,127,000	$12,345,000	$38,845,000	$82,764,000	$43,287,000	$15,821,000	$23,456,000	$11,938,000	$24,889,000
O & M costs	$/yr	$2,147,000	$1,560,000	$3,904,000	($3,243,000)	$168,000	$396,000	$1,336,000	$2,042,000	$1,863,000
TSS	kg/day	2,633	2,171	2,290	726	1,843	2,122	956	2,498	666
BOD	kg/day	1,170	965	1,145	363	819	943	425	1,110	296
AOX	kg/day	894	1,392	2,388	235	91	841	805	1,521	438
AOX	kg/t	1.56	1.89	1.87	0.57	1.59	0.89	1.89	1.37	1.47
Phosphorus	kg/day	47	39	40	29	33	38	17	44	12
TKN	kg/day	527	434	500	363	369	424	191	500	133
Train K2	*Eliminate molecular chlorine*									
Capital cost		$26,425,000	$18,964,000	$38,845,000	$84,462,000	$48,454,000	$35,522,000	$31,166,000	$17,281,000	$24,889,000
O & M costs	$/yr	$2,932,000	$3,047,000	$5,845,000	($2,833,000)	$530,000	$2,007,000	$2,661,000	$3,314,000	$2,199,000
TSS	kg/day	2,183	2,171	2,290	726	1,843	2,122	956	2,498	666
BOD	kg/day	970	965	1,145	363	819	943	425	1,110	296
AOX	kg/day	279	479	954	190	20	350	294	627	168
AOX	kg/t	0.49	0.65	0.75	0.46	0.35	0.37	0.69	0.56	0.56
Phosphorus	kg/day	39	39	40	29	33	38	17	44	12
TKN	kg/day	437	434	500	363	369	424	191	500	133

AOX data refers to the production rate of bleached pulp.
Effluent data for "1991" refers to calculated characteristics after projects which were physically committed before April 1991 are completed.
All effluent data shown above are long term averages.
Costs shown in parentheses are negative.

(Table continued on next page)

Table 36 Predicted effluent characteristics and costs for the kraft sub-sector *(continued)*

		Boise Fort Frances	CPFP Dryden	CPFP Thunder Bay	Domtar Cornwall	Domtar Red Rock	Eddy Espanola	James River Marathon	K-C Terrace Bay	Malette Smth. Rock
Train K3	*Eliminate molecular chlorine (including oxygen delignification)*									
Capital cost		$37,449,000	$33,789,000	$63,936,000	$93,102,000	$45,414,000	$35,522,000	$41,076,000	$45,317,000	$31,665,000
O & M costs	$/yr	$1,828,000	$1,878,000	$2,355,000	($3,471,000)	$429,000	$2,007,000	$1,872,000	$1,005,000	$1,527,000
TSS	kg/day	2,183	2,171	2,290	726	1,843	2,122	956	2,498	666
BOD	kg/day	970	965	1,145	363	819	943	425	1,110	296
AOX	kg/day	183	356	767	148	0	350	234	476	123
AOX	kg/t	0.32	0.48	0.6	0.36	0.	0.37	0.55	0.43	0.41
Phosphorus	kg/day	39	39	32	29	33	38	17	44	12
TKN	kg/day	437	434	400	363	369	424	191	500	133
Train K4	*Eliminate molecular chlorine (including extended cooking)*									
Capital cost		$73,098,000	$74,744,000	$125,362,000	$116,629,000		$119,876,000	$65,255,000	$97,451,000	$52,219,000
O & M costs	$/yr	($1,877,000)	$559,000	($602,000)	($6,485,000)	(Train 4 is not	($1,947,000)	($2,208,000)	($4,833,000)	$1,316,000
TSS	kg/day	2,183	2,171	2,290	726	applicable)	2,122	956	2,498	666
BOD	kg/day	970	965	1,145	363		943	425	1,110	296
AOX	kg/day	160	315	647	100		216	148	446	109
AOX	kg/t	0.28	0.43	0.51	0.24		0.23	0.35	0.4	0.37
Phosphorus	kg/day	39	39	28	29		38	17	44	12
TKN	kg/day	437	434	350	363		424	191	500	133
Train K5	*Eliminate molecular chlorine (including oxygen delignification and extended cooking)*									
Capital cost		$113,042,000	$119,163,000	$153,260,000	$129,433,000		$146,699,000	$85,586,000	$158,633,000	$69,025,000
O & M costs	$/yr	$3,494,000	$7,705,000	$3,691,000	($4,449,000)	(Train 5 is not	$6,896,000	$1,234,000	$1,113,000	$4,129,000
TSS	kg/day	970	965	2,290	726	applicable)	943	425	1,110	296
BOD	kg/day	485	483	1,145	363		472	213	555	148
AOX	kg/day	130	297	568	72		216	110	313	93
AOX	kg/t	0.23	0.4	0.44	0.18		0.23	0.26	0.28	0.31
Phosphorus	kg/day	39	39	28	29		38	17	44	12
TKN	kg/day	485	483	350	363		472	213	555	148

AOX data refers to the production rate of bleached pulp.

Effluent data for "1991" refers to calculated characteristics after projects which were physically committed before April 1991 are completed.

All effluent data shown above are long term averages.

Costs shown in parentheses are negative.

The unit costs of reducing the discharge of AOX, BOD, and TSS are shown in Figure 50 for the kraft mills.

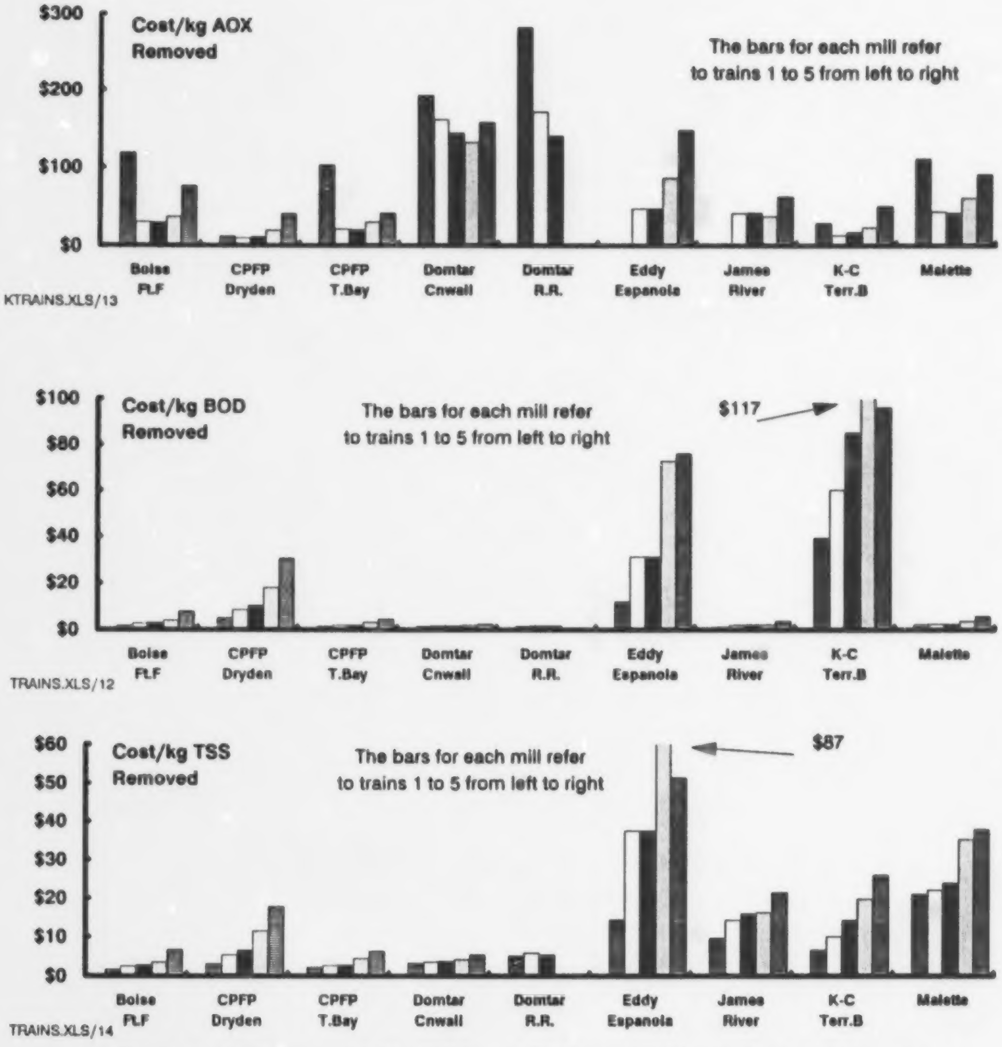

Figure 50 Unit cost of AOX, BOD and TSS removal in the kraft sub-sector

8.4 Costs for Sulphite/mechanical Sub-sector

The capital and operating costs for the mills in the sulphite/mechanical sub-sector are shown in Table 37 on the following pages, along with a brief summary of the predicted effluent characteristics.

Table 37 Predicted effluent characteristics and costs for the sulphite/mechanical sub-sector

		A-P Thunder Bay	A-P Fort William	A-P Prov.Paper	A-P Iroquois Falls	Boise Kenora	Q & O Thorold	St. Marys Sault Ste. M.	Spruce Falls Kapuskasing
Production and effluents from MISA 1990 sampling program									
Production rate	tonnes/day	472	371	424	801	929	840	506	978
Effluent flow	m^3/day	44,728	25,658	47,206	62,414	47,786	60,740	33,337	75,806
TSS	kg/day	1,904	1,190	1,594	7,625	3,431	2,932	6,012	7,900
BOD	kg/day	27,344	14,023	4,221	55,817	34,889	1,134	5,701	31,681
Phosphorus	kg/day	9	11	4	33	14	25	25	25
Total Kjeldahl Nitrogen	kg/day	77.3	75.1	55.1	194.	109.2	181.6	36.9	12.06
Train S1	*Activated sludge treatment*								
Capital cost		$31,075.000	$20,591,000	$17,144,000	$42,646,000	$32,589,000	$3,830,000	$15,550,000	$34,948,000
O & M costs	$/year	$3,934,000	$2,639,000	$1,761,000	$6,170,000	$4,614,000	$96,000	$1,957,000	$4,483,000
TSS	kg/day	472	371	424	801	929	840	506	978
BOD	kg/day	236	186	212	401	465	420	253	489
Phosphorus	kg/day	19	15	17	32	37	25	20	39
Total Kjeldahl Nitrogen	kg/day	236	186	212	401	465	181.6	253	489
Train S2	*Activated sludge treatment plus granular filter*								
Capital cost		$36,637,000	$25,240,000	$22,279,000	$50,912,000	$41,831,000	$12,397,000	$21,408,000	$44,555,000
O & M costs	$/year	$4,067,000	$2,795,000	$1,838,000	$6,497,000	$5,118,000	$462,000	$2,185,000	$4,896,000
TSS	kg/day	236	186	212	401	465	420	253	489
BOD	kg/day	165	130	148	280	325	294	177	342
Phosphorus	kg/day	9.4	7.4	8.5	16.0	18.6	16.8	10.1	19.6
Train S3	*Activated sludge treatment plus chemically assisted coagulation*								
Capital cost		$34,999,000	$23,890,000	$20,776,000	$48,412,000	$39,016,000	$9,800,000	$19,677,000	$41,622,000
O & M costs	$/year	$4,574,000	$3,194,000	$2,294,000	$7,358,000	$6,117,000	$1,365,000	$2,729,000	$5,947,000
TSS	kg/day	236	186	212	401	465	420	253	489
BOD	kg/day	165	130	148	280	325	294	177	342
Phosphorus	kg/day	9.4	7.4	8.5	16.0	18.6	16.8	10.1	19.6

All effluent data shown above are long term averages.

For Quebec and Ontario Paper Company, train 1 consists of the existing UNOX system with reduced flow. The predicted effluent quality must be considered as indicative only

TKN discharges are omitted for trains 2 and 3 due to lack of available data on performance. The values obtained will be somewhat lower than for train 1.

The unit costs for removal of BOD and TSS are shown in Figure 51. The unit costs for reduction of BOD in the discharges from the Quebec and Ontario Paper mill at Thorold are high, because it is the only mill in this sub-sector with a secondary treatment system, and the additional costs of upgrading it to BAT level are high relative to the reduction in BOD involved. Unit costs for the Abitibi-Price, Provincial Paper Division mill are high, since the mill presently discharges relatively little BOD.

Several mills would experience high unit costs for TSS removal, because they presently discharge relatively little, so that installation of a secondary treatment system would cause only a modest improvement.

The unit costs for BOD and TSS removal for the two mills in the corrugating sub-sector are also shown in Figure 51 since the technologies used are similar.

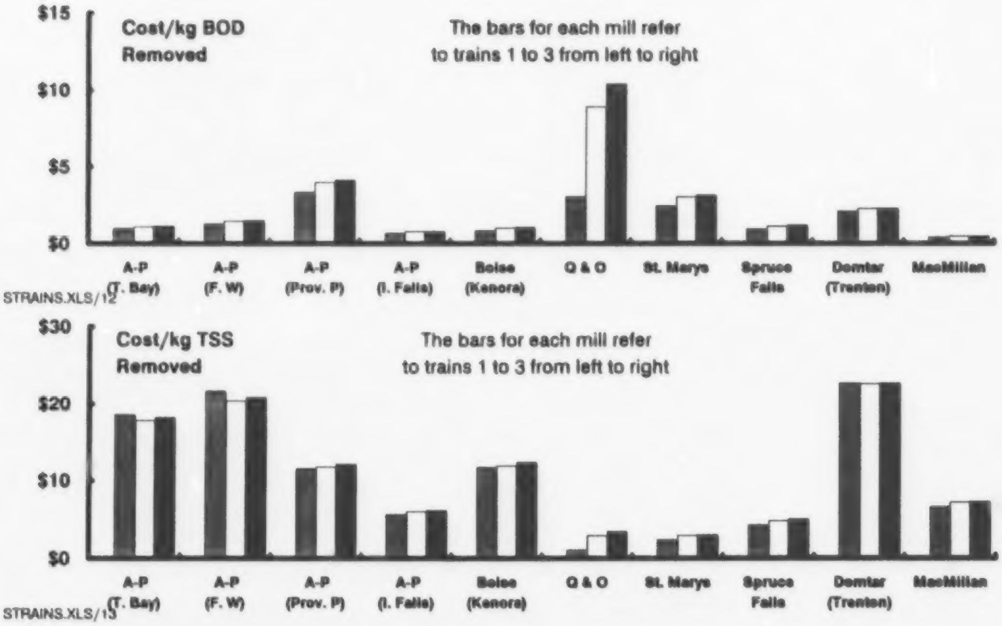

Figure 51 Unit cost of BOD and TSS removal in sulphite/mechanical and corrugating sub-sectors

8.5 Costs for Corrugating Sub-sector

The capital and operating costs for application of the three alternative technology trains to the two mills in the corrugating sub-sector are estimated to be as follows:

Table 38 Predicted effluent characteristics and costs for the corrugating sub-sector

		Domtar Trenton	MacMillan Sturgeon Falls
Base Case Effluent Data *(refer to note)*			
Production rate	t/day	327	274
Effluent flow	cu. m/day	4,015	13,698
TSS	kg/day	574	2,633
BOD	kg/day	5,258	19,655
Phosphorus	kg/day	3	28
Total Kjeldahl Nitrogen	kg/day	24	328
Train C1	*Activated sludge system*		
Capital cost		$10,475,000	$16,850,000
O & M costs	$/year	$2,056,000	$2,614,000
TSS	kg/day	88	274
BOD	kg/day	44	137
Phosphorus	kg/day	4	11
Total Kjeldahl Nitrogen	kg/day	44	137
Train C2	*Activated sludge system plus granular filter*		
Capital cost		$12,091,000	$20,565,000
O & M costs	$/year	$2,104,000	$2,765,000
TSS	kg/day	44	137
BOD	kg/day	31	96
Phosphorus	kg/day	1.8	5.5
Train C3	*Activated sludge system plus chemically assisted coagulation*		
Capital cost		$11,665,000	$19,505,000
O & M costs	$/year	$2,198,000	$3,059,000
TSS	kg/day	44	137
BOD	kg/day	31	96
Phosphorus	kg/day	1.8	5.5

Base case effluent data were estimated by the authors to reflect all projects to improve effluent which were physically committed before April 1991.

Table 39 Predicted effluent characteristics and costs for the deinking/board/fine papers/tissue sub-sector

		Beaver Thorold	Domtar St. Catharines	Eddy Ottawa	Noranda Thorold	K-C St. Catharines	K-C Huntsville	Trent Valley Trenton	Strathcona Napanee
Production and effluents from MISA 1990 sampling program									
Production rate	tonnes/day	225	161	166	270	108	100	305	178
Effluent flow	m^3/day	15,121	10,473	7,599	20,775	7,736	878	3,659	3,869
TSS	kg/day	759	423	560	1,000	59	5	514	243
BOD	kg/day	1,753	1,193	1,176	3,236	324	3	1,517	608
Phosphorus	kg/day	0.9	0.2	0.3	2.0	1.0	0.3	1	1.6
Total Kjeldahl Nitrogen	kg/day	33.2	19.5	30.9	31	19.5	5.8	13.7	39.3
Train F1	*(Refer to note)*	ASB	AST	AST	AST	None	ASB (exists)	ASB	ASB (exists)
Capital cost		$3,395,000	$6,489,000	$6,775,000	$10,652,000	$0	$0	$3,099,000	$500,000
O & M costs	$/year	$335,000	$978,000	$979,000	$1,296,000	$0	$0	$330,000	$53,000
TSS	kg/day	506	161	176	270	59	5	192	203
BOD	kg/day	225	81	88	135	169	3	85	90
Phosphorus	kg/day	9	6.4	7.1	10.8	1.0	0.3	3.4	1.6
Total Kjeldahl Nitrogen	kg/day	101	81	88	135	19.5	5.8	38	41
Train F2	*Activated sludge treatment*								
Capital cost		$7,387,000	$6,489,000	$6,775,000	$10,652,000	$0	$0	$6,591,000	$4,703,000
O & M costs	$/year	$1,036,000	$978,000	$979,000	$1,296,000	$0	$0	$1,007,000	$970,000
TSS	kg/day	225	161	176	270	59	5	85	47
BOD	kg/day	113	81	88	135	169	3	43	23
Phosphorus	kg/day	9	6.4	7.1	10.8	1.0	0.3	3.4	1.9
Total Kjeldahl Nitrogen	kg/day	113	81	88	135	19.5	5.8	43	23

All effluent data shown above are long term averages.

Train 1 uses the aerated stabilisation basins where space is available on the mill site. Otherwise activated sludge treatment is used.

For trains 2, 3 and 4, the process is uniform for all mills, unless no installation at all is required, so the process is not specified in each column.

K-C, St. Catharines mill effluent BOD was reduced as indicated after the 1990 MISA monitoring program by measures initiated by the company

(Table continued on next page)

Table 39 Predicted effluent characteristics and costs for the deinking/board/fine papers/tissue sub-sector *(continued)*

		Beaver Thorold	Domtar St. Catharines	Eddy Ottawa	Noranda Thorold	K-C St. Catharines	K-C Huntsville	Trent Valley Trenton	Strathcona Napanee
Train F3	*Activated sludge treatment plus granular filter*								
Capital cost		$10,599,000	$9,002,000	$9,462,000	$14,327,000	$0	$0	$8,176,000	$5,735,000
O & M cost	$/year	$1,160,000	$1,067,000	$1,076,000	$1,445,000	$0	$0	$1,054,000	$996,000
TSS	kg/day	113	81	88	135	59	5	43	23
BOD	kg/day	79	56	62	94	169	3	30	16
Phosphorus	kg/day	4.5	3.2	3.5	5.4	1.0	0.3	1.7	0.9
Train F4	*Activated sludge treatment plus chemically assisted coagulation*								
Capital cost		$9,694,000	$8,310,000	$8,717,000	$13,279,000	$0	$0	$7,760,000	$5,477,000
O & M costs	$/year	$1,402,000	$1,240,000	$1,266,000	$1,735,000	$0	$0	$1,146,000	$1,046,000
TSS	kg/day	113	81	88	135	59	5	43	23
BOD	kg/day	79	56	62	94	169	3	30	16
Phosphorus	kg/day	4.5	3.2	3.5	5.4	1.0	0.3	1.7	0.9

All effluent data shown above are long term averages

TKN discharges are omitted for trains 3 and 4 due to lack of available data on performance. The values obtained will be somewhat lower than for train 2.

8.6 Costs for Deinking/Board/Fine Papers/Tissue Sub-sector

The capital and operating costs for the mills in the deinking/board/fine papers/tissue sub-sector are shown in Table 39 on the following pages, along with a brief summary of the predicted effluent characteristics.

The unit costs for removal of BOD and TSS are shown in Figure 52. It is apparent that the variation between mills is less than in the other sub-sectors, but that the unit costs are substantially higher when comparing mills in this sub-sector which do not have secondary treatment to similar mills in the sulphite/mechanical sector. This is primarily due to the small scale of the treatment plants that would be required. In some cases, it would be more economical for the mills to connect to municipal sewage treatment systems.

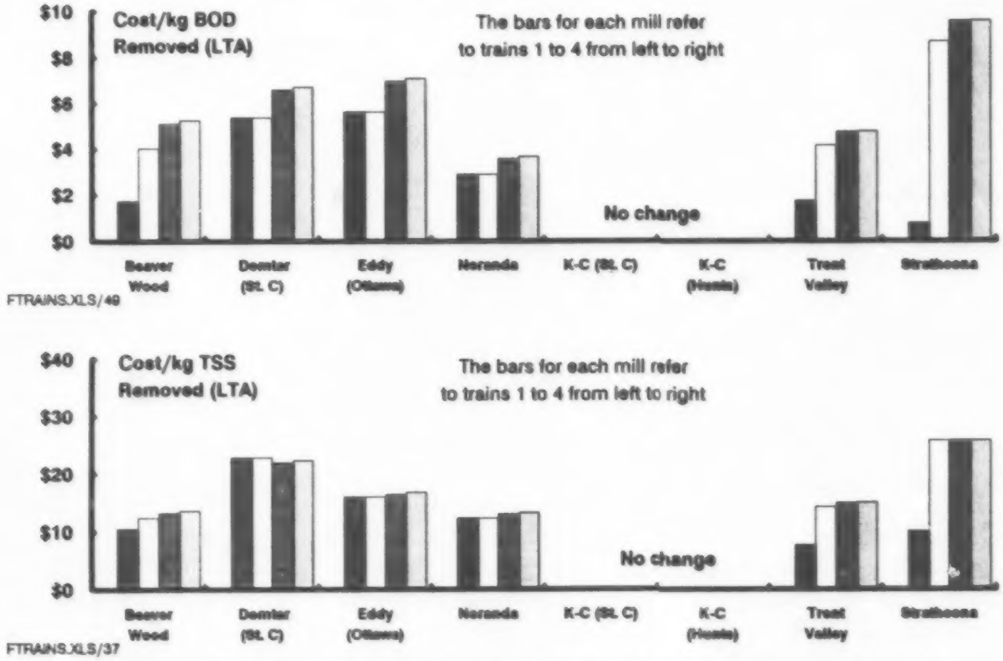

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Figure 52 Unit cost of BOD and TSS removal in deinking/board/fine papers/tissue sub-sector

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There are numerous references in the following list to proceedings of CPPA and TAPPI conferences as well as to these organisations' journals. Readers wishing to obtain copies of the original manuscripts may find it more convenient to contact the associations directly, rather than following the traditional library procedures. CPPA can be contacted in Montreal at 514 866 6621, and TAPPI in Atlanta at 800 446 9431 or 404 446 1400.

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Appendix A

Mill Descriptions

This appendix contains summary descriptions of the 27 mills addressed by this report.

The mills are listed by sub-sector, in the same order as they appear in the MISA effluent monitoring report:

Company	Town	Abbreviation	Mill No.
Kraft category			
Boise Cascade Canada Ltd.	Fort Frances	Boise (Ft. F)	06
Canadian Pacific Forest Products Ltd.	Dryden	CPFP (Dryden)	08
Canadian Pacific Forest Products Ltd.	Thunder Bay	CPFP (T. Bay)	09
Domtar Inc., Fine Papers Div.	Cornwall	Domtar (Cnwall)	10
Domtar Inc., Containerboard Division	Red Rock	Domtar (R.R.)	11
E.B. Eddy Forest Products Ltd.	Espanola	Eddy (Espanola)	14
James River-Marathon Ltd.	Marathon	James River	16
Kimberly-Clark Canada Inc.	Terrace Bay	K-C (Terr. B)	19
Malette Kraft Pulp and Paper Co.	Smooth Rock Falls	Malette	21
Sulphite-mechanical category			
Abitibi-Price Inc., Thunder Bay Div.	Thunder Bay	A-P (T. Bay)	04
Abitibi-Price Inc., Fort William Div.	Thunder Bay	A-P (F. W)	02
Abitibi-Price Inc., Provincial Papers Div.	Thunder Bay	A-P (Prov. P)	03
Abitibi-Price Inc., Iroquois Falls Div.	Iroquois Falls	A-P (I. Falls)	01
Boise Cascade Canada Ltd.	Kenora	Boise (Kenora)	07
Quebec and Ontario Paper Company Ltd.	Thorold	Q & O	23
St. Marys Paper Inc.	Sault Ste. Marie	St. Marys	24
Spruce Falls Power and Paper Company Ltd.	Kapuskasing	Spruce Falls	25
Corrugating category			
Domtar Inc., Containerboard Division	Trenton	Domtar (Tren)	13
MacMillan Bloedel Ltd.	Sturgeon Falls	MacMillan	20
Deinking-board-fine papers-tissue category			
Beaver Wood Fibre Company Ltd.	Thorold	Beaver Wood	05
Domtar Inc., Fine Papers Div.	St. Catharines	Domtar (St. C)	12
E. B. Eddy Forest Products Ltd.	Ottawa	Eddy (Ottawa)	15
Noranda Forest Inc., Recycled Papers	Thorold	Noranda	22
Kimberly-Clark Canada Inc.	St. Catharines	K-C (St. C)	18
Kimberly-Clark Canada Inc.	Huntsville	K-C (Hunts)	17
Trent Valley, Paperboard Industries Corporation	Trenton	Trent Valley	27
Strathcona Paper Company	Napanee	Strathcona	26

The Abitibi-Price, Thunder Bay Division mill was idled by the company in May 1991, and was expected to be idle for at least two years. It's future remains in doubt at the time of writing. All calculations in this report are based on the assumption that it will reopen with the same equipment and products as in 1990.

Announcements by Kimberly-Clark in June 1991 made it clear that the future of the Kapuskasing mill was also in doubt. All calculations in this report are based on the assumption that it will continue in operation, at a similar production rate to the 1990 operations.

Calculations and roundoff

The data presented have mostly been rounded off to improve readability. Some of the data shown in the following pages were calculated from other values shown on the same sheets and are presented for the reader's convenience. In some cases, the original data contained more significant figures than shown, and calculations were performed to the precision of these original values, prior to rounding off, so hand calculations based on the data herein may not balance exactly. This is particularly so for very low values, which are of course usually of little environmental significance.

Data sources

The sources of data in the following pages are:

Data concerning mill effluent toxicity prior to 1990 were taken from MoE "Report on the 1987 Industrial Direct Discharges in Ontario", the 1988 version of same, and from the Ministry's IMIS database for the 1989 data.

Definitions of production vary slightly from mill to mill and product to product, but the authors do not consider that these differences are significant in the context of this report. All mills were advised of our assumptions in this respect, and comments received are reflected in the data shown.

It was assumed that mills operate 355 days per year for purposes of calculations to relate annual data with daily data, where appropriate. Actual numbers of operating days vary, but analysis of detailed information on many of the mills indicated that most were within 2% of this value. Since the accuracy of the effluent measurements and cost estimates which most of the calculations are based on is substantially poorer than 2%, the use of a fixed number of operating days per year is considered to be a reasonable simplification.

Mill histories were extracted from the MISA Development Document (MISA 1989), with modifications based on the visits to the mills concerned and comments received from mill staff.

Pre 1990 data on effluent characteristics were extracted from Sprague (1991), Bonsor (1988).

Effluent flows, final product rates and characteristics were from MISA (1991).

Mill descriptions, capacities of internal operations and information on current construction were collected by questionnaires, mill visits and personal contacts.

Each mill was provided with a copy of the relevant datasheet(s) and invited to comment. Replies were received from 16 mills, and all comments were incorporated in the sheets which make up the remainder of this appendix.

Boise Cascade Canada Ltd., Fort Frances

Mill No: 06

Product Category: Kraft

FAX: 807-274-5992

Number of employees: 1000

Phone: 807-274-8816

Nominal Pulp Capacity

Unbleached Kraft	0	t/day
Bleached Kraft	575	
Groundwood	570	
Refiner Gwd	0	
TMP	0	
CTMP	0	
Ultra Hi Yield Sulphite	0	
High Yield Sulphite	0	
Low Yield Sulphite	0	
Semi Chemical	0	
De-inking	0	
Other pulp (inc waste)	0	

Nominal Product Capacity

Market Kraft	200	t/day
Newsprint	0	
Fine Paper	0	
Tissue	0	
Packaging	0	
Other	775	

Production 1990

	90th per- -centile	Average
Bleached	587	573 t/day
Total	1094	970

Summary of Effluent Characteristics

(based on first six months of 1990,

		90th per- -centile	Average
Flow cu m/day	=	82,920	77,276
TSS, kg/day	=	15,047	10,793
BOD, kg/day	=	11,652	9,470
AOX, kg/day	=	2,613	2,045
Flow cu m/ton	=		80

Acute Toxicity Tests (LC50 %)

	1987 TROUT	1988 TROUT	1989 TROUT	1990 TROUT	1990 DAPHNIA
				27	36
				55	100
				42	100
				77	100
				70	86
				77	100
Geometric Mean				54	85

Temperatures Minimum 15C Average 25C
Maximum 28C

Notes

Kraft production approx 70% full bleach, 30% semi bleach

Mill Processes

Wood supply: Kraft 90% jackpine, 10% spruce. Groundwood 55% spruce, 45% poplar

Proportion wood dry debarked: 50%

Proportion wood wet debarked: 50%

Proportion wood NOT debarked on site: %

Digester type (chemical pulp only): 6 Batch

Pulp Washing saltcake loss, line 1, kg/t pulp: 7.5

Pulp Washing saltcake loss, line 2, kg/t pulp:

Pulp Washing saltcake loss, line 3, kg/t pulp:

Typical Kappa 31,

Bleach sequence(s) Cd Eo HD

Chlorine dioxide substitution: 7%

In-plant effluent control measures

Closed screen room.

Existing effluent treatment

Primary: Clarifier for wet woodroom, 2 settling basins for kraft mill. Clarifier for paper mill

Secondary: Aerated basin (Approximately 3 day retention, 1417kw aeration)

Recipient: Rainy River

Outfall: Submerged diffuser

History

The mill was established in 1914 as a groundwood mill. In 1971 a kraft mill was added

Committed modifications which will modify effluents

23 t/day chlorine dioxide generator start-up mid 1991

Condensate stripping system startup 1991

Considering new ($18M) 7 day ASB farther from town, which will use existing system as polishing stage.

Canadian Pacific Forest Products Ltd., Dryden

Mill No: 08

Product Category: Kraft
FAX: 807-223-9317

Number of employees: 1030
Phone: 807-223-2323

Nominal Pulp Capacity

Unbleached Kraft	0	t/day
Bleached Kraft	830	
Groundwood	0	
Refiner Gwd	0	
TMP	0	
CTMP	0	
Ultra Hi Yield Sulphite	0	
High Yield Sulphite	0	
Low Yield Sulphite	0	
Semi Chemical	0	
De-inking	0	
Other pulp (inc waste)	0	

Nominal Product Capacity

Market Kraft	400	t/day
Newsprint	0	
Fine Paper	600	
Tissue	0	
Packaging	0	
Other	0	

Production 1990

	90th per-centile	Average
Bleached	915	735 t/day
Total	1258	965

Summary of Effluent Characteristics

(based on first six months of 1990,

		90th per-centile	Average
Flow cu m/day	=	100,000	91,707
TSS, kg/day	=	7,480	5,524
BOD, kg/day	=	4,214	3,132
AOX, kg/day	=	2,825	2,293
Flow cu m/ton	=		95

Acute Toxicity Tests (LC50 %)

	1987 TROUT	1988 TROUT	1989 TROUT	1990 TROUT	1990 DAPHNIA
				100	100
				64	100
				55	100
				78	100
				100	100
				78	100
Geometric Mean				80	100

Temperatures Minimum 13C Average —
Maximum 26C

Notes

Single line mill "Line 1" here is Swd, "2" Hwd. Dry debarking

Mill Processes

Wood supply: 75% black spruce and jackpine, rest hardwoods
Proportion wood dry debarked: 97%
Proportion wood wet debarked: 3%
Proportion wood NOT debarked on site: %

Digester type (chemical pulp only): 1 continuous 1982
Pulp Washing saltcake loss, line 1, kg/t pulp: 7.3
Pulp Washing saltcake loss, line 2, kg/t pulp: 5.7
Pulp Washing saltcake loss, line 3, kg/t pulp:
Typical Kappa31, 16

Bleach sequence(s) CdEoHDED
Chlorine dioxide substitution: 8%
Chlorine dioxide sub. line 2: 11%

In-plant effluent control measures

Spill recovery in evap, digester, recaust, tall oil, recovery, and a catch-all spill diversion for each of the six main sewers.

Existing effluent treatment

Primary: Clarifier

Secondary: 7-day aerated basin w/ jet aeration

Recipient: WABIGOON RIVER, WINNIPEG RIVER
Outfall: Underwater

History

Originally Dryden Timber and Power Company, was formed in 1910. Production of kraft pulp and sheathing began in 1913. In 1979, Great Lakes Forest Products Ltd. purchased the mill and undertook a major modernization and expansion program, which included up-to-date pollution abatement measures. Name changed to CPFP in late 1980's

Canadian Pacific Forest Products Ltd., Thunder Bay

Mill No: 09

Product Category: Kraft
FAX: 807-475-4801

Number of employees: 2033
Phone: 807-475-2110

Nominal Pulp Capacity

Unbleached Kraft	0	t/day
Bleached Kraft	1450	
Groundwood	570	
Refiner Gwd	0	
TMP	520	
CTMP	0	
Ultra Hi Yield Sulphite	0	
High Yield Sulphite	0	
Low Yield Sulphite	0	
Semi Chemical	0	
De-inking	0	
Other pulp (inc waste)	0	

Nominal Product Capacity

Market Kraft	1323	t/day
Newsprint	1226	
Fine Paper	0	
Tissue	0	
Packaging	0	
Other	0	

Production 1990

	90th per- -centile	Average	
Bleached	1540	1279	t/day
Total	2584	2290	

Summary of Effluent Characteristics

(based on first six months of 1990,

		90th per- -centile	Average
Flow cu m/day	=	190,000	173,931
TSS, kg/day	=	20,327	16,158
BOD, kg/day	=	59,408	49,014
AOX, kg/day	=	6,562	4,128
Flow cu m/ton	=		76

Acute Toxicity Tests (LC50 %)

	1987 TROUT	1988 TROUT	1989 TROUT	1990 TROUT	1990 DAPHNIA
				6	59
				55	77
				41	63
				38	100
				40	69
				41	100
Geometric Mean				31	76

Temperatures Minimum __ Average __
Maximum __

Notes

Bleaching data summarised here is A mill Softwood (line 1) and B Mill Hardwood (line 2)

Mill Processes

Wood supply: Softwood 75% Jackpine, 14% balsam, 11% spruce. Hardwood 100% aspen.
Proportion wood dry debarked: 85%
Proportion wood NOT debarked on site: 15%
Proportion wood wet debarked: %

Digester type (chemical pulp only): 2 Kamyrs. 1966 & 76
Pulp Washing saltcake loss, line 1, kg/t pulp: 8.7
Typical Kappa33, 12
Pulp Washing saltcake loss, line 2, kg/t pulp: 6.2
Pulp Washing saltcake loss, line 3, kg/t pulp:

Bleach sequence(s) DCEHDED/DCEoDED
Chlorine dioxide substitution: 55%
Chlorine dioxide sub. line 2: 60%

In-plant effluent control measures

Dry debarking, high (50%) substitution, closed screen room, condensate stripper (steam). Soap and turpentine recovery.

Existing effluent treatment

Primary: Clarifiers (4)

Secondary: None.

Recipient: Kaministiquia River, to Thunder Bay, L. Superior
Outfall: Diffuser

History

The mill is located in Thunder Bay and began operation in 1924 as a groundwood mill. A newsprint mill was constructed in 1927 and a sulphite mill was added in 1926. In 1966, a kraft mill was constructed followed by a second kraft mill in 1976. Spent sulphite liquors from the sulphite mill were recovered in the kraft mill recovery system until early 1991. TMP mill started up F eb 1991.
Formerly known as Great Lakes Forest Products Ltd.

Committed modifications which will modify effluents

Oxygen Activated sludge to treat about 2/3 effluent (phase I). TMP to replace some Gwd. Shut down sulphite mill April 1991.

Domtar Inc., Fine Papers Div., Cornwall

Mill No: 10

Product Category: Kraft
FAX: 613-938-4673

Number of employees: 1450
Phone: 613-938-4562

Nominal Pulp Capacity

Unbleached Kraft	0	t/day
Bleached Kraft	450	
Groundwood	0	
Refiner Gwd	0	
TMP	0	
CTMP	0	
Ultra Hi Yield Sulphite	0	
High Yield Sulphite	0	
Low Yield Sulphite	0	
Semi Chemical	0	
De-inking	0	
Other pulp (inc waste)	0	

Nominal Product Capacity

Market Kraft	0	t/day
Newsprint	0	
Fine Paper	825	
Tissue	0	
Packaging	0	
Other	0	

Production 1990

	90th per- -centile	Average
Bleached	480	412 t/day
Total	856	726

Summary of Effluent Characteristics

(based on first six months of 1990,

		90th per- -centile	Average
Flow cu m/day	=	135,000	126,049
TSS, kg/day	=	12,104	10,415
BOD, kg/day	=	26,398	22,053
AOX, kg/day	=	528	401
Flow cu m/ton	=		174

Acute Toxicity Tests (LC50 %)

	1987 TROUT	1988 TROUT	1989 TROUT	1990 TROUT	1990 DAPHNIA
				56	100
				75	39
				100	100
				89	100
				95	100
				66	27
Geometric Mean				79	69

Temperatures Minimum 18C Average 25C
Maximum 35C

Notes

Anthraquinone used to raise pulping yield
Black liquor discharges high due to limited recovery boiler capacity. AOX low relative to bleach chemicals used, perhaps due to reaction with black liquor in sewer.
Passed 6/6 daphnia and 4/6 toxicity late90

Mill Processes

Wood supply: 100% hardwood
Proportion wood dry debarked: 70%
Proportion wood wet debarked: %
Proportion wood NOT debarked on site: 30%

Digester type (chemical pulp only): 6 digesters 1961-76
Pulp Washing saltcake loss, line 1, kg/t pulp:
Pulp Washing saltcake loss, line 2, kg/t pulp:
Pulp Washing saltcake loss, line 3, kg/t pulp:
Typical Kappa 0, 15

Bleach sequence(s) CdEoDED
Chlorine dioxide substitution: 45%

In-plant effluent control measures

Steam stripper, fibre spill recovery in upper floors of bleaching and digester areas, lime spill control
Lime spill clarifier and filter to eliminate recaust plant losses in 1988
Reclamation of wet press effluents
Fibre recovery system for primary

Existing effluent treatment

Primary: Clarifier

Secondary: None

Recipient: St. Lawrence River
Outfall: Submerged Diffuser.

History

The mill was established in 1883 as a groundwood mill. In 1888 the mill added a sulphite pulping operation. A soda pulp mill was added in 1927 but was converted to a kraft mill in the 1940's. The sulphite and groundwood mills were shut down in the 1970's. The mill purchases market pulps to supplement its furnish.

Domtar Inc., Containerboard Division, Red Rock

Mill No: 11

Product Category: Kraft
FAX: 807-866-2532

Number of employees: 650
Phone: 807-886-2211

Nominal Pulp Capacity

Unbleached Kraft	700	t/day
Bleached Kraft	50	
Groundwood	200	
Refiner Gwd	0	
TMP	0	
CTMP	0	
Ultra Hi Yield Sulphite	0	
High Yield Sulphite	0	
Low Yield Sulphite	0	
Semi Chemical	0	
De-inking	0	
Other pulp (inc waste)	725	

Nominal Product Capacity

Market Kraft	0	t/day
Newsprint	250	
Fine Paper	0	
Tissue	0	
Packaging	0	
Other	650	

Production 1990

	90th per- -centile	Average
Bleached	75	57 t/day
Total	976	819

Summary of Effluent Characteristics

(based on first six months of 1990,

		90th per- -centile	Average
Flow cu m/day	=	99,870	95,187
TSS, kg/day	=	7,273	6,260
BOD, kg/day	=	19,588	15,716
AOX, kg/day	=	223	169
Flow cu m/ton	=		116

Acute Toxicity Tests (LC50 %)

	1987 TROUT	1988 TROUT	1989 TROUT	1990 TROUT	1990 DAPHNIA
				39	100
				33	100
				52	81
				37	100
				87	100
					39
Geometric Mean				46	83

Temperatures

Minimum __ Average __
Maximum __

Notes

Nominal product rates. (1a) Hwd 60t/d 29 Kappa
(1b)Fines 99 t/d 51 Kappa
(2) 500 t/d Kappa 100 for liner
(3) 70 t/d bleachable 35 Kappa.

Mill Processes

Wood supply: 40% hardwood, 45% Spruce, 15% Jackpine
Proportion wood dry debarked: %
Proportion wood wet debarked: 65%
Proportion wood NOT debarked on site: 35%

Digester type (chemical pulp only): MD fines + 11 Batch
Pulp Washing saltcake loss, line 1, kg/t pulp: 29.0
Pulp Washing saltcake loss, line 2, kg/t pulp: 31.0
Pulp Washing saltcake loss, line 3, kg/t pulp: 10.0
Typical Kappa99, 30

Bleach sequence(s) CEH
Chlorine dioxide substitution:

In-plant effluent control measures

Alum used in primary clarifer to reduce toxicity. Steam stripper for kraft condensates. Black liquor spill recovery. Boiler at 85% load.

Existing effluent treatment

Primary: Clarifier

Secondary: None

Recipient: NIPIGON BAY, LAKE SUPERIOR
Outfall: Surface with foam control

History

The mill was built in 1945 as a sulphite mill and was converted to a kraft mill in 1959. In 1961, the mill was purchased by Domtar Inc. The mill was expanded and renovated in 1970.

E.B. Eddy Forest Products Ltd., Espanola

Mill No: 14

Product Category: Kraft
FAX: 705-869-4901

Number of employees: 600
Phone: 705-869-2020

Nominal Pulp Capacity

Unbleached Kraft	0	t/day
Bleached Kraft	910	
Groundwood	0	
Refiner Gwd	0	
TMP	0	
CTMP	0	
Ultra Hi Yield Sulphite	0	
High Yield Sulphite	0	
Low Yield Sulphite	0	
Semi Chemical	0	
De-inking	0	
Other pulp (inc waste)	0	

Nominal Product Capacity

Market Kraft	738	t/day
Newsprint	0	
Fine Paper	0	
Tissue	0	
Packaging	0	
Other	172	

Production 1990

	90th per- -centile	Average
Bleached	1216	943 t/day
Total	1216	943

Summary of Effluent Characteristics

(based on first six months of 1990,

		90th per- -centile	Average
Flow cu m/day	=	119,257	98,577
TSS, kg/day	=	4,525	2,745
BOD, kg/day	=	2,407	1,689
AOX, kg/day	=	1,069	841
Flow cu m/ton	=		105

Acute Toxicity Tests (LC50 %)

	1987 TROUT	1988 TROUT	1989 TROUT	1990 TROUT	1990 DAPHNIA
				100	100
				100	100
				100	100
				100	100
				100	100
					100
Geometric Mean				100	100

Temperatures Minimum 20C Average 25C
Maximum 32C

Notes

Kappa numbers shown are after oxygen delignification.

Mill Processes

Wood supply: 46% Jackpine, 8% spruce, 45% birch/maple and poplar
Proportion wood dry debarked: 100%
Proportion wood NOT debarked on site: %
Proportion wood wet debarked: %

Digester type (chemical pulp only): Kamyr(Swd) & 5 Batch
Pulp Washing saltcake loss, line 1, kg/t pulp: 8.0
Typical Kappa20, 10
Pulp Washing saltcake loss, line 2, kg/t pulp: 14.0
Pulp Washing saltcake loss, line 3, kg/t pulp:

Bleach sequence(s) OCdEHD/ODcEoHD
Chlorine dioxide substitution: 60%
Chlorine dioxide sub. line 2: 30%

In-plant effluent control measures

Oxygen delignification, MCC on softwood (retrofit, to 24 Kappa).
Steam stripper for condensates.

Existing effluent treatment

Primary: Clarifier for paper mill, settling basins for pulp mill

Secondary: 7-10 day aerated basin w/1230kw aeration. 24,000 cu. m. capacity spill basin.

Recipient: SPANISH RIVER, NORTH CHANNEL OF LAKE HURON Outfall: Diffuser

History

The mill commenced operations in 1898, and was converted to kraft process by the Kalamazoo Vegetable Parchment Co. in 1943. Eddy purchased mill in 1969. Extensive modernisation from 1975 to 1983, including first oxygen delignification systems in Canada.

James River-Marathon Ltd., Marathon

Mill No: 16

Product Category: Kraft
FAX: 807-229-2954

Number of employees: 380
Phone: 807-229-1200

Nominal Pulp Capacity

Unbleached Kraft	0	t/day
Bleached Kraft	433	
Groundwood	0	
Refiner Gwd	0	
TMP	0	
CTMP	0	
Ultra Hi Yield Sulphite	0	
High Yield Sulphite	0	
Low Yield Sulphite	0	
Semi Chemical	0	
De-inking	0	
Other pulp (inc waste)	0	

Nominal Product Capacity

Market Kraft	500	t/day
Newsprint	0	
Fine Paper	0	
Tissue	0	
Packaging	0	
Other	0	

Production 1990

	90th per- -centile	Average
Bleached	523	425 t/day
Total	523	425

Summary of Effluent Characteristics

(based on first six months of 1990,

		90th per- -centile	Average
Flow cu m/day	=	66,424	61,888
TSS, kg/day	=	3,508	2,578
BOD, kg/day	=	15,079	12,564
AOX, kg/day	=		3,000
Flow cu m/ton	=		146

Acute Toxicity Tests (LC50 %)

	1987 TROUT	1988 TROUT	1989 TROUT	1990 TROUT	1990 DAPHNIA
				14	13
				14	19
				14	15
				14	14
				33	81
				29	17
Geometric Mean				18	20

Temperatures Minimum __ Average __
Maximum __

Notes

Single line mill (1) below is softwood (about 90% of production), (2) is hardwood.
AOX data in MISA report not credible. Value shown is estimate by N. McCubbin Consultants Inc.

Mill Processes

Wood supply: 54% spruce, 34% Jackpine, 10% Poplar, 2% balsam
Proportion wood dry debarked: 10%
Proportion wood wet debarked: %
Proportion wood NOT debarked on site: 90%

Digester type (chemical pulp only): Batch
Pulp Washing saltcake loss, line 1, kg/t pulp: 7.0
Pulp Washing saltcake loss, line 2, kg/t pulp: 8.0
Pulp Washing saltcake loss, line 3, kg/t pulp:
Typical Kappa 30,

Bleach sequence(s) CdEoHED
Chlorine dioxide substitution: 46%
Chlorine dioxide sub. line 2: 51%

In-plant effluent control measures

High (50%) chlorine dioxide substitution. (100% 1991)
Spill collection 1986
New brownstock washers 1989
Sewer conductivity network 86

Existing effluent treatment

Primary: Clarifier

Secondary: None

Recipient: LAKE SUPERIOR

Outfall: Foam basin, multiport diffuser

History

The mill was constructed a kraft mill in 1945. In the late 1970's the mill embarked on a modernization program and in 1984 installed a foam retention lagoon and diffuser outfall into Lake Superior which eliminated a long-standing aesthetic problem associated with the mill's discharge.

Committed modifications which will modify effluents

(DC)EoDED bleaching sequence started-up May 91, up to 100% substitution.

Kimberly-Clark Canada Inc., Terrace Bay

Mill No: 19

Product Category: Kraft
FAX: 807-825-3322

Number of employees: 730
Phone: 807-825-3211

Nominal Pulp Capacity

Unbleached Kraft	0	t/day
Bleached Kraft	1200	
Groundwood	0	
Refiner Gwd	0	
TMP	0	
CTMP	0	
Ultra Hi Yield Sulphite	0	
High Yield Sulphite	0	
Low Yield Sulphite	0	
Semi Chemical	0	
De-inking	0	
Other pulp (inc waste)	0	

Nominal Product Capacity

Market Kraft	1200	t/day
Newsprint	0	
Fine Paper	0	
Tissue	0	
Packaging	0	
Other	0	

Production 1990

	90th per- -centile	Average	
Bleached	1308	1110	t/day
Total	1308	1110	

Summary of Effluent Characteristics

(based on first six months of 1990,

		90th per- -centile	Average
Flow cu m/day	=	109,553	95,122
TSS, kg/day	=	5,838	4,279
BOD, kg/day	=	2,430	1,408
AOX, kg/day	=	2,520	1,931
Flow cu m/ton	=		86

Acute Toxicity Tests (LC50 %)

	1987 TROUT	1988 TROUT	1989 TROUT	1990 TROUT	1990 DAPHNIA
				100	100
				100	100
				100	100
				100	100
				100	100
				100	100
Geometric Mean				100	100

Temperatures Minimum 12C Average 20C
Maximum 25C

Notes

Mill operating data were made available on a confidential basis.
None of the data supplied indicated that effluents would be outside typical industry ranges.

Mill Processes

Wood supply: 30% poplar, 70% pine, spruce and fir.
Proportion wood dry debarked: 75%
Proportion wood wet debarked: %
Proportion wood NOT debarked on site: 25%

Digester type (chemical pulp only): 17 batch
Pulp Washing saltcake loss, line 1, kg/t pulp: 6.0
Pulp Washing saltcake loss, line 2, kg/t pulp: 6.0
Pulp Washing saltcake loss, line 3, kg/t pulp:
Typical Kappa27, 12

Bleach sequence(s) DCPEoDED, DCEDED
Chlorine dioxide substitution:

In-plant effluent control measures

Excellent liquor spill system. Also fibre spill recovery and spill pond for total effluent.
Steam stripper for contaminated condensates.
Eliminated Hypo stages

Existing effluent treatment

Primary: Clarifier (2)

Secondary: Aerated stabilisation basin commissioned September 1989

Recipient: BLACKBIRD CREEK, JACKFISH BAY, LAKE SUPERIOR Outfall: None

History

The mill was constructed in 1948 as a small (320 tonne per day) kraft mill. Over the years, the production was steadily increased and in 1978, a new second kraft pulping mill was added. In 1981, a fire occurred at the mill and during subsequent reconstruction, several new process changes were incorporated.

Malette Kraft Pulp and Paper Co., Smooth Rock Falls

Mill No: 21

Product Category: Kraft
FAX: 705-338-4506

Number of employees: 300
Phone: 705-338-2741

Nominal Pulp Capacity

Unbleached Kraft	0	t/day
Bleached Kraft	340	
Groundwood	0	
Refiner Gwd	0	
TMP	0	
CTMP	0	
Ultra Hi Yield Sulphite	0	
High Yield Sulphite	0	
Low Yield Sulphite	0	
Semi Chemical	0	
De-inking	0	
Other pulp (inc waste)	0	

Nominal Product Capacity

Market Kraft	321	t/day
Newsprint	0	
Fine Paper	0	
Tissue	0	
Packaging	0	
Other	0	

Production 1990

	90th per- -centile	Average
Bleached	390	298 t/day
Total	373	296

Summary of Effluent Characteristics

(based on first six months of 1990,

		90th per- -centile	Average
Flow cu m/day	=	54,470	50,664
TSS, kg/day	=	2,093	1,512
BOD, kg/day	=	10,088	8,310
AOX, kg/day	=	1,773	1,294
Flow cu m/ton	=		171

Acute Toxicity Tests (LC50 %)

	1987 TROUT	1988 TROUT	1989 TROUT	1990 TROUT	1990 DAPHNIA
				53	77
				19	15
				30	26
				30	24
				32	28
				24	23
Geometric Mean				30	28

Temperatures Minimum __ Average __
Maximum __

Notes

Major modernisation program in progress 1991, including oxygen delignification to kappa 15, steam stripping condensates, closed screen room and new recovery boiler. Predict 50% reduction in BOD

Mill Processes

Wood supply: 65% blackspruce, 35% jackpine
Proportion wood dry debarked: %
Proportion wood wet debarked: %
Proportion wood NOT debarked on site: %

Digester type (chemical pulp only): Kamyr, MCC added 91
Pulp Washing saltcake loss, line 1, kg/t pulp: 16.0
Pulp Washing saltcake loss, line 2, kg/t pulp:
Pulp Washing saltcake loss, line 3, kg/t pulp:
Typical Kappa 23,

Bleach sequence(s) CdEoDED
Chlorine dioxide substitution: 16%

In-plant effluent control measures

Existing effluent treatment

Primary: Clarifier

Secondary: None

Recipient: MATTAGAMI RIVER,MOOSE RIVER, JAMES BAY
Outfall: None

History

The mill was originally built in 1916 as a sulphite mill and was converted to a kraft mill in 1965.

Committed modifications which will modify effluents

16 t/day chlorine dioxide plant to raise substitution (mid 1991)
New recovery and evaporater system

Abitibi-Price Inc., Thunder Bay Div., Thunder Bay

Mill No: 04

Product Category: Sulphite-Mechanical
FAX: 807-683-3732
Number of employees: 325
Phone: 807-683-6235

Nominal Pulp Capacity

Unbleached Kraft	0	t/day
Bleached Kraft	0	
Groundwood	340	
Refiner Gwd	0	
TMP	0	
CTMP	0	
Ultra Hi Yield Sulphite	0	
High Yield Sulphite	140	
Low Yield Sulphite	0	
Semi Chemical	0	
De-inking	0	
Other pulp (inc waste)	0	

Nominal Product Capacity

Market Kraft	0	t/day
Newsprint	460	
Fine Paper	0	
Tissue	0	
Packaging	0	
Other	0	

Production 1990

	90th per--centile	Average
Bleached		t/day
Total	517	472

Summary of Effluent Characteristics

(based on first six months of 1990,

		90th per--centile	Average
Flow cu m/day	=	48,838	44,728
TSS, kg/day	=	2,475	1,904
BOD, kg/day	=	34,392	27,344
AOX, kg/day	=		
Flow cu m/ton	=		95

Acute Toxicity Tests (LC50 %)

	1987 TROUT	1988 TROUT	1989 TROUT	1990 TROUT	1990 DAPHNIA
	13	25	15	15	32
	32	13	30	15	27
	23	14	13	21	25
	19	28		18	39
		25		23	34
				24	37
Geometric Mean	21	20	18	19	32

Temperatures Minimum __ Average __
Maximum __

Notes

Wet debarking. Effluent flow measuring weir rebuilt late 1989, and new data indicates that 1987-1989 flows were about 20% low.

Mill Processes

Wood supply:
Proportion wood dry debarked: %
Proportion wood wet debarked: %
Proportion wood NOT debarked on site: %

In-plant effluent control measures

Existing effluent treatment

Primary: Woodroom clarifier. 2 settling basins for whole mill effluent

Secondary: None

Recipient: Thunder Bay. Lake Superior.

Outfall: Surface creek. MoE reports no problems

History

The mill currently operates a high yield sulphite pulping process and produces groundwood pulp and newsprint.

Committed modifications which will modify effluents

Mill was idled for two years by company in early 1991.

Abitibi-Price Inc., Fort William Div., Thunder Bay

Mill No: 02

Product Category: Sulphite-Mechanical
FAX: 807-622-7355

Number of employees: 300
Phone: 807-625-7403

Nominal Pulp Capacity

Unbleached Kraft	0	t/day
Bleached Kraft	0	
Groundwood	220	
Refiner Gwd	0	
TMP	0	
CTMP	0	
Ultra Hi Yield Sulphite	130	
High Yield Sulphite	0	
Low Yield Sulphite	0	
Semi Chemical	0	
De-inking	0	
Other pulp (inc waste)	0	

Nominal Product Capacity

Market Kraft	0	t/day
Newsprint	390	
Fine Paper	0	
Tissue	0	
Packaging	0	
Other	0	

Production 1990

	90th per- -centile	Average
Bleached		t/day
Total	428	371

Summary of Effluent Characteristics

(based on first six months of 1990,

		90th per- -centile	Average
Flow cu m/day	=	29,359	25,658
TSS, kg/day	=	1,690	1,190
BOD, kg/day	=	18,319	14,023
AOX, kg/day	=		
Flow cu m/ton	=		69

Acute Toxicity Tests (LC50 %)

	1987 TROUT	1988 TROUT	1989 TROUT	1990 TROUT	1990 DAPHNIA
	10	10	14	11	17
	10	10	19	9	24
	2	9	2	5	15
	2	10		7	18
	11	1		8	22
	20	10			
Geometric Mean	7	7	8	8	19

Temperatures

Minimum __ Average __
Maximum __

Notes

Only dioxin found in 1990 monitoring was Octo.

Mill Processes

Wood supply: Softwood. Chips purchased for UHYS (SCMP), roundwood for groundwood mill
Proportion wood dry debarked: %
Proportion wood NOT debarked on site: 30%
Proportion wood wet debarked: 70%

In-plant effluent control measures

Existing effluent treatment

Primary: Clarifier, settling ponds
Clarifier for woodroom, SCMP and Gwd cleaner rejects. All thru ponds
Secondary:
None
Recipient:
Thunder Bay, Lake Superior
Outfall: 2 surface outfalls to semi-impounded bay

History

The mill was built as a groundwood mill. Subsequently, a sulphite mill was constructed which operated until the end of 1981 when it was replaced with a chemi-mechanical pulping process.

Committed modifications which will modify effluents

Deink plant startup 1992
Reducing water use.

Abitibi-Price Inc., Provincial Papers Div., Thunder Bay

Mill No: 03

Product Category: Sulphite-Mechanical
FAX: 807-683-2372

Number of employees: 250
Phone: 807-683-2208

Nominal Pulp Capacity

Unbleached Kraft	0	t/day
Bleached Kraft	0	
Groundwood	100	
Refiner Gwd	0	
TMP	0	
CTMP	0	
Ultra Hi Yield Sulphite	0	
High Yield Sulphite	0	
Low Yield Sulphite	0	
Semi Chemical	0	
De-inking	0	
Other pulp (inc waste)	0	

Nominal Product Capacity

Market Kraft	0	t/day
Newsprint	0	
Fine Paper	500	
Tissue	0	
Packaging	0	
Other	0	

Production 1990

	90th per- -centile	Average
Bleached		t/day
Total	489	424

Summary of Effluent Characteristics

(based on first six months of 1990,

		90th per- -centile	Average
Flow cu m/day	=	53,818	47,206
TSS, kg/day	=	2,433	1,594
BOD, kg/day	=	5,972	4,221
AOX, kg/day	=		
Flow cu m/ton	=		111

Acute Toxicity Tests (LC50 %)

	1987 TROUT	1988 TROUT	1989 TROUT	1990 TROUT	1990 DAPHNIA
	100	100	100	100	100
	100	100		100	100
	100	100		100	100
		100		100	100
		100			100
					100
Geometric Mean	100	100	100	100	100

Temperatures

Minimum __ Average __
Maximum __

Notes

Dry debarking

Mill Processes

Wood supply:
Proportion wood dry debarked: %
Proportion wood wet debarked: %
Proportion wood NOT debarked on site: %

In-plant effluent control measures

Existing effluent treatment

Primary: Woodroom clarifier and serpentine settling basin

Secondary: None

Recipient: THUNDER BAY, LAKE SUPERIOR

Outfall: Surface

History

The mill was originally constructed as a sulphite mill. In 1922 the mill began paper production and later, groundwood pulp production was added. In 1978 the sulphite pulping process was shut down and the mill now purchases market pulps to provide furnish.

Abitibi-Price Inc., Iroquois Falls Div., Iroquois Falls

Mill No: 01

Product Category: Sulphite-Mechanical
FAX: 705-258-3350

Number of employees: 900
Phone: 705-258-3220

Nominal Pulp Capacity

Unbleached Kraft	0	t/day
Bleached Kraft	0	
Groundwood	540	
Refiner Gwd	0	
TMP	0	
CTMP	0	
Ultra Hi Yield Sulphite	0	
High Yield Sulphite	272	
Low Yield Sulphite	0	
Semi Chemical	0	
De-inking	0	
Other pulp (inc waste)	0	

Nominal Product Capacity

Market Kraft	0	t/day
Newsprint	880	
Fine Paper	0	
Tissue	0	
Packaging	0	
Other	0	

Production 1990

	90th per-centile	Average
Bleached		t/day
Total	906	801

Summary of Effluent Characteristics

(based on first six months of 1990,

		90th per-centile	Average
Flow cu m/day	=	69,910	62,414
TSS, kg/day	=	9,527	7,625
BOD, kg/day	=	63,907	55,817
AOX, kg/day	=		
Flow cu m/ton	=		78

Acute Toxicity Tests (LC50 %)

	1987 TROUT	1988 TROUT	1989 TROUT	1990 TROUT	1990 DAPHNIA
	10	23	7	7	7
	35	23		6	14
	22			7	14
				7	18
				7	14
				6	8
Geometric Mean	20	23	7	7	12

Temperatures Minimum 6C Average 28C
Maximum 37C

Notes

Wet debarking. 1988 Effluent flow and TSS discharge provided by mill, because MoE data had obvious typographical error.

Mill Processes

Wood supply:
Proportion wood dry debarked: %
Proportion wood wet debarked: %

Proportion wood NOT debarked on site: %

In-plant effluent control measures

Woodrom water usage reduction in 1991.

Existing effluent treatment

Primary: 2 Clarifiers

Secondary: None

Recipient: Abitibi River

Outfall: Diffuser in river

History

The mill operates a high yield sulphite pulping process (without recovery) and produces groundwood pulp and newsprint.

Boise Cascade Canada Ltd., Kenora

Mill No: 07

Product Category: Sulphite-Mechanical
FAX: 807-468-6168

Number of employees: 850
Phone: 807-468-6411

Nominal Pulp Capacity

Unbleached Kraft	0	t/day
Bleached Kraft	0	
Groundwood	563	
Refiner Gwd	0	
TMP	0	
CTMP	0	
Ultra Hi Yield Sulphite	260	
High Yield Sulphite	0	
Low Yield Sulphite	0	
Semi Chemical	0	
De-inking	0	
Other pulp (inc waste)	0	

Nominal Product Capacity

Market Kraft	0	t/day
Newsprint	950	
Fine Paper	0	
Tissue	0	
Packaging	0	
Other	0	

Production 1990

	90th per--centile	Average
Bleached		t/day
Total	1057	929

Summary of Effluent Characteristics

(based on first six months of 1990,

		90th per--centile	Average
Flow cu m/day	=	52,200	47,786
TSS, kg/day	=	4,244	3,431
BOD, kg/day	=	43,521	34,889
AOX, kg/day	=		
Flow cu m/ton	=		51

Acute Toxicity Tests (LC50 %)

	1987 TROUT	1988 TROUT	1989 TROUT	1990 TROUT	1990 DAPHNIA
	2	3	6	2	9
	7	3	5	2	100
	4	12	2	5	6
	6	7	11	2	100
	3	14	11	4	9
				3	20
Geometric Mean	4	6	6	3	19

Temperatures Minimum __ Average 35C
Maximum __

Notes

Purchased kraft makes up shortfall in pulping capacity.

Mill Processes

Wood supply:
Proportion wood dry debarked: 100%
Proportion wood wet debarked: %
Proportion wood NOT debarked on site: %

In-plant effluent control measures

Effluent segregation
Sulphite pulping converted to ultra high yield to reduce BOD.

Existing effluent treatment

Primary: Clarifier

Secondary: None

Recipient: WINNIPEG RIVER

Outfall: Diffuser

History

The mill operates a ultra high yield sulphite pulping process (without recovery) and produces groundwood pulp and newsprint.
TMP under construction to replace some groundwood.

Quebec and Ontario Paper Company Ltd., Thorold

Mill No: 23

Product Category: Sulphite-Mechanical
FAX: 416-227-2353
Number of employees: 1150
Phone: 416-227-1121

Nominal Pulp Capacity

Unbleached Kraft	0	t/day
Bleached Kraft	0	
Groundwood	0	
Refiner Gwd	0	
TMP	352	
CTMP	0	
Ultra Hi Yield Sulphite	0	
High Yield Sulphite	0	
Low Yield Sulphite	0	
Semi Chemical	0	
De-inking	432	
Other pulp (inc waste)	0	

Nominal Product Capacity

Market Kraft	0	t/day
Newsprint	871	
Fine Paper	0	
Tissue	0	
Packaging	0	
Other	0	

Production 1990

	90th per- -centile	Average
Bleached		t/day
Total	1004	840

Summary of Effluent Characteristics

(based on first six months of 1990,

		90th per- -centile	Average
Flow cu m/day	=	66,615	60,740
TSS, kg/day	=	3,931	2,932
BOD, kg/day	=	1,675	1,134
AOX, kg/day	=		
Flow cu m/ton	=		72

Acute Toxicity Tests (LC50 %)

	1987 TROUT	1988 TROUT	1989 TROUT	1990 TROUT	1990 DAPHNIA
	100	100	100	100	100
	100	100	100	100	100
	100	100	100	100	100
		100		100	100
				100	100
				100	100
Geometric Mean	100	100	100	100	100

Temperatures Minimum __ Average __
Maximum __

Notes

No debarking
Sulphite mill shut down end 1987, with major cut in BOD Mill invested approx $20 million in 1980 on in-plant, primary and secondary treatment. Annual operating costs approx $3 million (1989).

Mill Processes

Wood supply:
Proportion wood dry debarked: %
Proportion wood wet debarked: %
Proportion wood NOT debarked on site: %

In-plant effluent control measures

Existing effluent treatment

Primary: Clarifier. Deink froth to combined sludge dewatering. Sludge to agricultural fertiliser

Secondary: Oxygen Activated Sludge. Sludge to gravity thickener, then to press. All used as fertiliser

Recipient: Twelve Mile Creek
Outfall: Submerged

History

The mill originally manufactured the newsprint from sulphite and groundwood pulps. In the 1980's, the mill constructed a deinking plant for recycling newsprint and in 1987 the sulphite pulping operation was shut down. A high rate biological treatment system which utilizes oxygen, was installed in 1980. The mill is the only one in Canada which recycles newspapers (although several are under construction or are plannd).

St. Marys Paper Inc., Sault Ste. Marie

Mill No: 24

Product Category: Sulphite-Mechanical
FAX: 705-942-2097

Number of employees: 520
Phone: 705-942-6075

Nominal Pulp Capacity

Unbleached Kraft	0	t/day
Bleached Kraft	0	
Groundwood	450	
Refiner Gwd	0	
TMP	0	
CTMP	0	
Ultra Hi Yield Sulphite	0	
High Yield Sulphite	0	
Low Yield Sulphite	0	
Semi Chemical	0	
De-inking	0	
Other pulp (inc waste)	0	

Nominal Product Capacity

Market Kraft	0	t/day
Newsprint	0	
Fine Paper	0	
Tissue	0	
Packaging	0	
Other	550	

Production 1990

	90th per- -centile	Average
Bleached		t/day
Total	629	506

Summary of Effluent Characteristics

(based on first six months of 1990,

		90th per- -centile	Average
Flow cu m/day	=	36,061	33,337
TSS, kg/day	=	7,964	6,012
BOD, kg/day	=	9,526	5,701
AOX, kg/day	=		
Flow cu m/ton	=		66

Acute Toxicity Tests (LC50 %)

	1987 TROUT	1988 TROUT	1989 TROUT	1990 TROUT	1990 DAPHNIA
	25	21	100	39	20
	22	27		34	40
	14	11		39	53
	21	27		17	26
	24	14		32	65
	20	14		78	57
Geometric Mean	28	17	100	36	40

Temperatures Minimum __ Average __
Maximum __

Notes

Wood is dry debarked to about 70%, then wet drums to finish (in series). New PM fall 1988.

Mill Processes

Wood supply:
Proportion wood dry debarked: 70%
Proportion wood wet debarked: 30%
Proportion wood NOT debarked on site: %

In-plant effluent control measures

Existing effluent treatment

Primary: 33m dia Clarifier

Secondary: None. Clarifier attains 35% BOD reduction, and significant toxicity redn. with 22 mg/l alum addition

Recipient: ST. MARY'S RIVER

Outfall: In Hydro-turbine tailrace

History

The mill originally produced newsprint from sulphite and groundwood pulps. The sulphite pulping operations were shut down in the early 1980's with the sulphite pulp being replaced with purchased bleached kraft pulp. The mill currently produces groundwood specialty papers.

Spruce Falls Power and Paper Company Ltd., Kapuskasing

Mill No: 25

Product Category: Sulphite-Mechanical
FAX: 705-337-9700

Number of employees: 1200
Phone: 705-337-1311

Nominal Pulp Capacity

Unbleached Kraft	0	t/day
Bleached Kraft	0	
Groundwood	500	
Refiner Gwd	0	
TMP	320	
CTMP	0	
Ultra Hi Yield Sulphite	0	
High Yield Sulphite	0	
Low Yield Sulphite	128	
Semi Chemical	0	
De-inking	0	
Other pulp (inc waste)	0	

Nominal Product Capacity

Market Kraft	0	t/day
Newsprint	1000	
Fine Paper	0	
Tissue	0	
Packaging	0	
Other	0	

Production 1990

	90th per- -centile	Average
Bleached		t/day
Total	1096	983

Summary of Effluent Characteristics

(based on first six months of 1990,

		90th per- -centile	Average
Flow cu m/day	=	93,346	75,806
TSS, kg/day	=	10,080	7,900
BOD, kg/day	=	40,204	31,681
AOX, kg/day	=		
Flow cu m/ton	=		77

Acute Toxicity Tests (LC50 %)

	1987 TROUT	1988 TROUT	1989 TROUT	1990 TROUT	1990 DAPHNIA
	40	35	24	5	20
	47	25	10	7	23
	73		13	11	52
	51			12	24
	17			29	64
				28	61
Geometric Mean	41	30	15	12	36

Temperatures

Minimum __ Average __
Maximum __

Notes

Probable reduction or termination of operations announced by company early 1991
BOD permitted varies with river conditions. 26-34 t/d. daily max 40. 1988 flow est.

Mill Processes

Wood supply:
Proportion wood dry debarked: 20%
Proportion wood wet debarked: 67%
Proportion wood NOT debarked on site: 13%

In-plant effluent control measures

Refer to history.

Existing effluent treatment

Primary: Clarifiers

Secondary: None

Recipient: KAPUSKASING RIVER

Outfall:

History

The mill originally produced newsprint from groundwood and calcium-based sulphite pulps. In 1964, a new magnesium-based sulphite process (Magnefite) which included chemical recovery of spent pulping liquors was installed. In 1976, a new 200 tonne/day thermo-mechanical pulp mill (TMP) was installed.
In 1978 a 135 t/day bleached market sulphite operation was shut down, reducing the mill's BOD discharge by 20 t/day.
The calcium sulphite operations were shut down in 1982.
In 1981, the TMP mill was expanded to 300 t/day.
Sanitary sewage collected 1982
Clean effluents segregated 1981
Second primary clarifier added 1982
Magnefite spill system, red liquor neutralisation and improved rejects installed mid 1980's.

Domtar Inc., Containerboard Division, Trenton

Mill No: 13

Product Category: Corrugating
FAX: 613-392-3026

Number of employees: 140
Phone: 613-392-6505

Nominal Pulp Capacity

Unbleached Kraft	0	t/day
Bleached Kraft	0	
Groundwood	0	
Refiner Gwd	0	
TMP	0	
CTMP	0	
Ultra Hi Yield Sulphite	0	
High Yield Sulphite	0	
Low Yield Sulphite	0	
Semi Chemical	200	
De-inking	0	
Other pulp (inc waste)	156	

Nominal Product Capacity

Market Kraft	0	t/day
Newsprint	0	
Fine Paper	0	
Tissue	0	
Packaging	338	
Other	0	

Production 1990

	90th per- -centile	Average
Bleached		t/day
Total	382	327

Summary of Effluent Characteristics

(based on first six months of 1990,

		90th per- -centile	Average
Flow cu m/day	=	4,380	4,015
TSS, kg/day	=	928	574
BOD, kg/day	=	7,730	5,258
AOX, kg/day	=		
Flow cu m/tcn	=		12

Acute Toxicity Tests (LC50 %)

	1987 TROUT	1988 TROUT	1989 TROUT	1990 TROUT	1990 DAPHNIA
	25	13		42	100
	25	50		22	63
	35	48		26	45
	25	28		36	65
	20			38	89
	32			17	48
Geometric Mean	29	30		29	65

Temperatures Minimum 23C Average 46C
Maximum 50C

Notes

Wood mostly roundwood, washed on site, but not debarked

Mill Processes

Wood supply:
Proportion wood dry debarked: %
Proportion wood wet debarked: %

Proportion wood NOT debarked on site: 100%

In-plant effluent control measures

Extensive recycle of white water

Existing effluent treatment

Primary: Basins for recycle

Secondary: Spent liquor disposal by road spreading

Recipient: TRENT RIVER, BAY OF QUINTE, LAKE ONTARIO

Outfall: Submerged

History

Originally the mill produced soda pulp from cereal straws but in 1956 this process was replaced with a NSSC process for pulping wood. In the 1970's the mill was modernized and the NSSC process was converted to sodium carbonate semi-chemical pulping which eliminated the use of sulphur. Spent pulping liquors are collected and made available for use as a dust suppressant. The mill also processes recycled waste corrugating medium and board.

MacMillan Bloedel Ltd., Sturgeon Falls

Mill No: 20

Product Category: Corrugating
FAX: 705-753-4154

Number of employees: 420
Phone: 705-753-2170

Nominal Pulp Capacity

Unbleached Kraft	0	t/day
Bleached Kraft	0	
Groundwood	0	
Refiner Gwd	0	
TMP	115	
CTMP	0	
Ultra Hi Yield Sulphite	0	
High Yield Sulphite	0	
Low Yield Sulphite	0	
Semi Chemical	240	
De-inking	0	
Other pulp (inc waste)	0	

Nominal Product Capacity

Market Kraft	0	t/day
Newsprint	0	
Fine Paper	0	
Tissue	0	
Packaging	0	
Other	355	

Production 1990

	90th per- -centile	Average
Bleached		t/day
Total	301	274

Summary of Effluent Characteristics
(based on first six months of 1990,

		90th per- -centile	Average
Flow cu m/day	=	16,379	13,698
TSS, kg/day	=	4,212	2,633
BOD, kg/day	=	49,138	36,886
AOX, kg/day	=		
Flow cu m/ton	=		50

Acute Toxicity Tests (LC50 %)

	1987 TROUT	1988 TROUT	1989 TROUT	1990 TROUT	1990 DAPHNIA
	10			10	13
				6	8
				5	5
				4	15
				4	11
Geometric Mean	10			5	10

Temperatures Minimum 23C Average 27C
Maximum 30C

Notes
BOD5 limit set by requirement for 47% oxygen saturation in river

Mill Processes
Wood supply:
Proportion wood dry debarked: %
Proportion wood wet debarked: %
Proportion wood NOT debarked on site: 100%

In-plant effluent control measures

Existing effluent treatment
Primary: WW to flotation clarifier

Secondary: Anaerobic treatment system, (without subsequent aerobic treatment)

Recipient: STURGEON R., to Lake Nipissing.

Outfall: Diffuser, no reports of foam etc.

History
Mill built to produce market pulp in 1898;
The mill was shut down in 1930.;In 1946, the mill was reopened and subsequently equipment was installed to produce hardboard from TMP and corrugating medium using the neutral sulphite semi-chemical pulping process. Waste pulping liquors are not recovered, but an anaerobic treatment system was installed in 1989/90.

Beaver Wood Fibre Company Ltd., Thorold

Mill No: 05

Product Category: Deinking/board/fine paper
FAX: 416-227-8120

Number of employees: 160
Phone: 416-227-6651

Nominal Pulp Capacity

Unbleached Kraft	0	t/day
Bleached Kraft	0	
Groundwood	0	
Refiner Gwd	0	
TMP	0	
CTMP	0	
Ultra Hi Yield Sulphite	0	
High Yield Sulphite	0	
Low Yield Sulphite	0	
Semi Chemical	0	
De-inking	0	
Other pulp (inc waste)	0	

Nominal Product Capacity

Market Kraft	0	t/day
Newsprint	0	
Fine Paper	0	
Tissue	0	
Packaging	0	
Other	294	

Production 1990

	90th per--centile	Average
Bleached		t/day
Total	347	225

Summary of Effluent Characteristics

(based on first six months of 1990,

		90th per--centile	Average
Flow cu m/day	=	16,500	15,121
TSS, kg/day	=	969	759
BOD, kg/day	=	2,142	1,753
AOX, kg/day	=		
Flow cu m/ton	=		67

Acute Toxicity Tests (LC50 %)

	1987 TROUT	1988 TROUT	1989 TROUT	1990 TROUT	1990 DAPHNIA
	100	57	100	100	100
	100	100	100	100	100
		100		100	51
				100	37
				100	100
				100	100
Geometric Mean	100	83	100	100	76

Temperatures Minimum __ Average __
Maximum __

Notes

No debarking

Furnish is 100% waste, boxboard, news, and blank news. Top plies all blank news. Pulping with water only, no chemicals except for sodium hydrosulphite.

Mill Processes

Wood supply:
Proportion wood dry debarked: %
Proportion wood wet debarked: %
Proportion wood NOT debarked on site: %

In-plant effluent control measures

Existing effluent treatment

Primary: Clarifier (sludge recycled to product) & spill pond

Secondary: None

Recipient: BEAVERDAMS CREEK TO 12 MILE CREEK, L. ONTARIO Outfall: Surface

History

Prior to 1976, the mill produced groundwood pulp and purchased market pulp and waste paper products to manufacture newsprint and board. The mill now uses 100% purchased recycled waste paper and board as feedstock and no longer manufactures newsprint.

Domtar Inc., Fine Papers Div., St. Catharines

Mill No: 12

Product Category: Deink/board/fine paper
FAX: 416-680-3274

Number of employees: 300
Phone: 416-680-3228

Nominal Pulp Capacity

Unbleached Kraft	0 t/day
Bleached Kraft	0
Groundwood	0
Refiner Gwd	0
TMP	0
CTMP	0
Ultra Hi Yield Sulphite	0
High Yield Sulphite	0
Low Yield Sulphite	0
Semi Chemical	0
De-inking	0
Other pulp (inc waste)	0

Nominal Product Capacity

Market Kraft	0 t/day
Newsprint	0
Fine Paper	200
Tissue	0
Packaging	0
Other	0

Production 1990

	90th per--centile	Average t/day
Bleached		
Total	196	161

Summary of Effluent Characteristics

(based on first six months of 1990,

		90th per--centile	Average
Flow cu m/day	=	13,012	10,473
TSS, kg/day	=	564	423
BOD, kg/day	=	1,777	1,193
AOX, kg/day	=		
Flow cu m/ton	=		65

Acute Toxicity Tests (LC50 %)

	1987 TROUT	1988 TROUT	1989 TROUT	1990 TROUT	1990 DAPHNIA
	100	83	100	74	100
	100	100	100	81	100
		100	100	100	100
		100		100	55
				100	
Geometric Mean	100	95	100	90	86

Temperatures Minimum 18C Average 19C
Maximum 21C

Notes

No debarking. Secondary fibre is from converter waste, and is NOT chemically processed. Primary sludge to agriculatural use by contractor, about $60/dry ton.

Mill Processes

Wood supply:
Proportion wood dry debarked: %
Proportion wood wet debarked: %
Proportion wood NOT debarked on site: %

In-plant effluent control measures

Savealls for white water and fibre recovery

Existing effluent treatment

Primary: 75 ft dia clarifier. 8-10 tpd sludge to Niagara Waste for mulch.
Taster screw press.
Secondary:
None, but floc aid in clarifier reduces BOD 25%.
Recipient:
Twelve Mile Creek
Outfall:

History

Today the mill no longer produces pulp but manufactures fine papers from purchased pulps and recycled clean waste paper.

E. B. Eddy Forest Products Ltd., Ottawa

Mill No: 15

Product Category: Deink/board/fine paper
FAX: 613-782-2515
Number of employees: 600
Phone: 613-782-2641

Nominal Pulp Capacity

Unbleached Kraft	0 t/day
Bleached Kraft	0
Groundwood	0
Refiner Gwd	0
TMP	0
CTMP	0
Ultra Hi Yield Sulphite	0
High Yield Sulphite	0
Low Yield Sulphite	0
Semi Chemical	0
De-inking	0
Other pulp (inc waste)	0

Nominal Product Capacity

Market Kraft	0 t/day
Newsprint	0
Fine Paper	170
Tissue	0
Packaging	0
Other	0

Production 1990

	90th per- -centile	Average
Bleached		t/day
Total	234	166

Summary of Effluent Characteristics

(based on first six months of 1990,

		90th per- -centile	Average
Flow cu m/day	=	8,819	7,599
TSS, kg/day	=	870	560
BOD, kg/day	=	1,661	1,176
AOX, kg/day	=		
Flow cu m/ton	=		46

Acute Toxicity Tests (LC50 %)

	1987 TROUT	1988 TROUT	1989 TROUT	1990 TROUT	1990 DAPHNIA
	100	100		55	37
	53	100		100	45
	100			44	19
				45	33
				81	100
				100	95
Geometric Mean	81	100		67	46

Temperatures Minimum 13C Average 23C
Maximum 35C

Notes

No toxicity test 1989. No debarking

Mill Processes

Wood supply:
Proportion wood dry debarked: %
Proportion wood wet debarked: %
Proportion wood NOT debarked on site: %

In-plant effluent control measures

Existing effluent treatment

Primary: Clarifier, with flocullant aids

Secondary: None

Recipient: OTTAWA RIVER, ST. LAWRENCE RIVER

Outfall: Submerged, sometimes bubbles visible

History

In 1979, the paperboard mill was shut down and the mill currently produces fine papers. The mill management is essentially integrated with the E.B. Eddy paper mill in Hull, Quebec which lies across the Ottawa River. The process waters and effluents are separate.

Noranda Forest Inc., Recycled Papers, Thorold

Mill No: 22

Product Category: Deink/board/fine paper
FAX: 416-227-8919

Number of employees: 625
Phone: 416-227-5271

Nominal Pulp Capacity

Unbleached Kraft	0	t/day
Bleached Kraft	0	
Groundwood	0	
Refiner Gwd	0	
TMP	0	
CTMP	0	
Ultra Hi Yield Sulphite	0	
High Yield Sulphite	0	
Low Yield Sulphite	0	
Semi Chemical	0	
De-inking	115	
Other pulp (inc waste)	0	

Nominal Product Capacity

Market Kraft	0	t/day
Newsprint	0	
Fine Paper	320	
Tissue	0	
Packaging	0	
Other	0	

Production 1990

	90th per- -centile	Average
Bleached		t/day
Total	284	245

Summary of Effluent Characteristics

(based on first six months of 1990,

		90th per- -centile	Average
Flow cu m/day	=	23,239	20,775
TSS, kg/day	=		
BOD, kg/day	=	4,797	3,236
AOX, kg/day	=		
Flow cu m/ton	=		85

Acute Toxicity Tests (LC50 %)

	1987 TROUT	1988 TROUT	1989 TROUT	1990 TROUT	1990 DAPHNIA
	81	7	47	29	57
	16	0	28	81	100
	3	0		18	22
		2		4	7
		28		11	17
		18			
Geometric Mean	16	3	36	18	27

Temperatures Minimum __ Average __
Maximum __

Notes

Ontario reports LC50 24-39%
No debarking. Toxicity apparently due to residual chlorine from bleaching (CH sequence). Mill feels reducing Cl with Sodium metabisulphite will raise LC50 to 100%. Cl residual can be up to 25 ppm winter to 3 in summer.

Mill Processes

Wood supply:
Proportion wood dry debarked: %
Proportion wood wet debarked: %
Proportion wood NOT debarked on site: %

Digester type (chemical pulp only):
Pulp Washing saltcake loss, line 1, kg/t pulp:
Pulp Washing saltcake loss, line 2, kg/t pulp:
Pulp Washing saltcake loss, line 3, kg/t pulp:
Typical Kappa 0,

Bleach sequence(s)
Chlorine dioxide substitution:

In-plant effluent control measures

Existing effluent treatment

Primary: Clarifier for all effluent, including activated sludge system discharge.

Secondary: Activated sludge system, for deink washing filtrate only

Recipient: Twelve Mile Creek
Outfall: Into underground section of Canal

History

The mill manufactures fine papers from deinked recycled waste paper and purchased pulps. In the 1970's, the mill installed a high rate biological oxidation system to treat the effluent from the washers in the deinking plant.

Kimberly-Clark Canada Inc., St. Catharines

Mill No: 18

Product Category: Deink/board/fine paper
FAX: 416-227-1899

Number of employees: 200
Phone: 416-227-1161

Nominal Pulp Capacity

Unbleached Kraft	0	t/day
Bleached Kraft	0	
Groundwood	0	
Refiner Gwd	0	
TMP	0	
CTMP	0	
Ultra Hi Yield Sulphite	0	
High Yield Sulphite	0	
Low Yield Sulphite	0	
Semi Chemical	0	
De-inking	0	
Other pulp (inc waste)	0	

Nominal Product Capacity

Market Kraft	0	t/day
Newsprint	0	
Fine Paper	20	
Tissue	60	
Packaging	0	
Other	40	

Production 1990

	90th per- -centile	Average
Bleached		t/day
Total	114	108

Summary of Effluent Characteristics

(based on first six months of 1990,

		90th per- -centile	Average
Flow cu m/day	=	8,990	7,736
TSS, kg/day	=	102	59
BOD, kg/day	=	538	324
AOX, kg/day	=		
Flow cu m/ton	=		72

Acute Toxicity Tests (LC50 %)

	1987 TROUT	1988 TROUT	1989 TROUT	1990 TROUT	1990 DAPHNIA
	100	100	100	100	100
	100	100	100	100	100
		100	100	100	100
				100	100
				100	100
				100	100
Geometric Mean	100	100	100	100	100

Temperatures

Minimum 14C Average 20C
Maximum 32C

Notes

Secondary fibre, making towelling

Mill Processes

Wood supply:
Proportion wood dry debarked: %
Proportion wood wet debarked: %
Proportion wood NOT debarked on site: %

In-plant effluent control measures

Existing effluent treatment

Primary: 106 ft dia clarifier and two settling ponds.

Secondary: None

Recipient: Twelve Mile Creek

Outfall: Surface. Cleaner than recipient at visit

History

The mill was constructed as a groundwood mill. The mill now uses purchased pulps to produce tissue, crepe paper and fine paper products.

Kimberly-Clark Canada Inc., Huntsville

Mill No: 17

Product Category: Deink/board/fine paper
FAX: 705-789-1291

Number of employees: 250
Phone: 705-789-4487

Nominal Pulp Capacity

Unbleached Kraft	0	t/day
Bleached Kraft	0	
Groundwood	0	
Refiner Gwd	0	
TMP	0	
CTMP	0	
Ultra Hi Yield Sulphite	0	
High Yield Sulphite	0	
Low Yield Sulphite	0	
Semi Chemical	0	
De-inking	0	
Other pulp (inc waste)	0	

Nominal Product Capacity

Market Kraft	0	t/day
Newsprint	0	
Fine Paper	0	
Tissue	0	
Packaging	0	
Other	92	

Production 1990

	90th per- -centile	Average
Bleached		t/day
Total	118	100

Summary of Effluent Characteristics

(based on first six months of 1990,

		90th per- -centile	Average
Flow cu m/day	=	1,482	878
TSS, kg/day	=	8	5
BOD, kg/day	=	4	3
AOX, kg/day	=		
Flow cu m/ton	=		9

Acute Toxicity Tests (LC50 %)

	1987 TROUT	1988 TROUT	1989 TROUT	1990 TROUT	1990 DAPHNIA
	100	100		100	100
	100	100		100	100
		100		100	100
Geometric Mean	100	100		100	100

Temperatures

Minimum 6C Average 9C
Maximum 13C

Notes

No toxicity test 1989. COD limit .8 TPD, P limit.3 kg/d. Disposal by irrigation TSS 0.003 t/dy, BOD 0.05 t/dy.

Mill Processes

Wood supply:
Proportion wood dry debarked: %
Proportion wood wet debarked: %
Proportion wood NOT debarked on site: %

In-plant effluent control measures

Existing effluent treatment

Primary: Clarifier w/ 80% recycle - 20% to settling basion

Secondary: ASB. Percolating beds (winter) and spray irrigation on forest land (summer) as tertiary treatment.

Recipient: Big East River

Outfall: Underwater

History

The mill uses purchased bleached kraft pulp to manufacture tissue. It is the largest tissue mill in Canada.

Trent Valley, Paperboard Industries Corp., Trenton

Mill No: 27

Product Category: Deink/board/fine paper
FAX: 613-392-2485

Number of employees: 279
Phone: 613-392-1231

Nominal Pulp Capacity

Unbleached Kraft	0	t/day
Bleached Kraft	0	
Groundwood	0	
Refiner Gwd	0	
TMP	0	
CTMP	0	
Ultra Hi Yield Sulphite	0	
High Yield Sulphite	0	
Low Yield Sulphite	0	
Semi Chemical	0	
De-inking	0	
Other pulp (inc waste)	0	

Nominal Product Capacity

Market Kraft	0	t/day
Newsprint	0	
Fine Paper	0	
Tissue	0	
Packaging	325	
Other	0	

Production 1990

	90th per- -centile	Average
Bleached		t/day
Total	342	305

Summary of Effluent Characteristics

(based on first six months of 1990,

		90th per- -centile	Average
Flow cu m/day	=	4,265	3,659
TSS, kg/day	=	918	514
BOD, kg/day	=	1,970	1,517
AOX, kg/day	=		
Flow cu m/ton	=		12

Acute Toxicity Tests (LC50 %)

	1987 TROUT	1988 TROUT	1989 TROUT	1990 TROUT	1990 DAPHNIA
	51	7	7	90	65
	52	47	100	42	100
	35	24	66	100	78
	65	51	100	100	100
	53		100	100	100
	21		66	100	52
Geometric Mean	48	25	56	85	80

Temperatures Minimum 10C Average 23C
Maximum 35C

Notes

TSS requirement is 140 kg/d
1989 IMIS data shows .5kg Phosphorus/day.

Mill Processes

Wood supply:
Proportion wood dry debarked: %
Proportion wood wet debarked: %
Proportion wood NOT debarked on site: %

In-plant effluent control measures

Existing effluent treatment

Primary: Clarifier (flotation) (2)

Secondary: None

Recipient: TRENT RIVER, BAY OF QUINTE, LAKE ONTARIO Outfall: Submerged

History

The mill is made up of two separate mills, the east and west mills. The east mill, constructed in 1880, originally used straw and rags to make paperboard but today uses recycled wastepaper and board. In 1976, the west mill was built and incorporated modern-day recycling and screening technologies into its manufacturing operations.

Strathcona Paper Company, Napanee

Mill No: 26

Product Category: Deink/board/fine paper
FAX: 613-378-6158

Number of employees: 160
Phone: 613-378-6672

Nominal Pulp Capacity

Unbleached Kraft	0	t/day
Bleached Kraft	0	
Groundwood	0	
Refiner Gwd	0	
TMP	0	
CTMP	0	
Ultra Hi Yield Sulphite	0	
High Yield Sulphite	0	
Low Yield Sulphite	0	
Semi Chemical	0	
De-inking	0	
Other pulp (inc waste)	0	

Nominal Product Capacity

Market Kraft	0	t/day
Newsprint	0	
Fine Paper	0	
Tissue	0	
Packaging	170	
Other	168	

Production 1990

	90th per--centile	Average
Bleached		t/day
Total	217	178

Summary of Effluent Characteristics

(based on first six months of 1990,

		90th per--centile	Average
Flow cu m/day	=	4,519	3,869
TSS, kg/day	=	380	243
BOD, kg/day	=	1,004	608
AOX, kg/day	=		
Flow cu m/ton	=		22

Acute Toxicity Tests (LC50 %)

	1987 TROUT	1988 TROUT	1989 TROUT	1990 TROUT	1990 DAPHNIA
		100		100	100
		100		40	63
		100		50	100
		100		81	87
				100	100
				100	100
Geometric Mean		100		74	90

Temperatures Minimum 1C Average 13C
Maximum 26C

Notes

No debarking. Allowable BOD discharge depends on flow. Mill complied 100% in 1988.

Mill Processes

Wood supply:
Proportion wood dry debarked: %
Proportion wood wet debarked: %
Proportion wood NOT debarked on site: %

In-plant effluent control measures

Existing effluent treatment

Primary: Flotation Clarifier and Settling Basins

Secondary: Aerated basins (13 days retention w/ 67 kw aeration).

Recipient: NAPANEE RIVER, BAY OF QUINTE, LAKE ONTARIO

Outfall: Submerged, not visible at visit

History

The mill initially used neighbouring forests as a source of wood. The mill no longer pulps wood but now uses clean recycled waste paper and board as its source of fibre.

Appendix B

Ontario Mill Effluents in 1990

The data collected in the 1990 MISA monitoring program (MISA 1991) were the principal source of information on existing mill effluent characteristics for this report. Summaries that were prepared to assist in analyzing the applicability of the various effluent control technologies are reproduced on the following pages. The data was obtained from the MISA office in February 1991, and reflects the available corrections until April 18th 1991. **This should not be considered as an authorized release of the data, but simply a convenient summary of certain aspects, in the form that was required for preparation of this report.**

The data concerning each mill are presented in the same order as used elsewhere in this report, and in many MISA reports, as follows:

Kraft Sub-sector

		Page
Boise Cascade Canada Ltd.	Fort Frances	2
Canadian Pacific Forest Products Ltd.	Dryden	7
Canadian Pacific Forest Products Ltd.	Thunder Bay	12
Domtar Inc., Fine Papers Div.	Cornwall	17
Domtar Inc., Containerboard Division	Red Rock	22
E.B. Eddy Forest Products Ltd.	Espanola	27
James River-Marathon Ltd.	Marathon	32
Kimberly-Clark Canada Inc.	Terrace Bay	37
Malette Kraft Pulp and Paper Co.	Smooth Rock Falls	42

Sulphite-Mechanical Sub-sector

Abitibi-Price Inc., Thunder Bay Div.	Thunder Bay	48
Abitibi-Price Inc., Fort William Div.	Thunder Bay	53
Abitibi-Price Inc., Provincial Papers Div.	Thunder Bay	58
Abitibi-Price Inc., Iroquois Falls Div.	Iroquois Falls	63
Boise Cascade Canada Ltd.	Kenora	68
Quebec and Ontario Paper Company Ltd.	Thorold	73
St. Marys Paper Inc.	Sault Ste. Marie	78
Spruce Falls Power and Paper Company Ltd.	Kapuskasing	83

Corrugating Sub-sector

Domtar Inc., Containerboard Division	Trenton	89
MacMillan Bloedel Ltd.	Sturgeon Falls	94

Deinking-Board-Fine Papers-Tissue Sub-sector

Beaver Wood Fibre Company Ltd.	Thorold	100
Domtar Inc., Fine Papers Div.	St. Catharines	105
E. B. Eddy Forest Products Ltd.	Ottawa	110
Noranda Forest Inc., Recycled Papers	Thorold	115
Kimberly-Clark Canada Inc.	St. Catharines	120
Kimberly-Clark Canada Inc.	Huntsville	125
Trent Valley, Paperboard Industries Corporation	Trenton	130
Strathcona Paper Company	Napanee	135

(Notes)

Kraft Sub-sector

		Page
Boise Cascade Canada Ltd.	Fort Frances	2
Canadian Pacific Forest Products Ltd.	Dryden	7
Canadian Pacific Forest Products Ltd.	Thunder Bay	12
Domtar Inc., Fine Papers Div.	Cornwall	17
Domtar Inc., Containerboard Division	Red Rock	22
E.B. Eddy Forest Products Ltd.	Espanola	27
James River-Marathon Ltd.	Marathon	32
Kimberly-Clark Canada Inc.	Terrace Bay	37
Malette Kraft Pulp and Paper Co.	Smooth Rock Falls	42

Table 1b. Halogenated volatiles (ATG16). Boise Cascade Canada Ltd. (Fort Frances). (Date: 8-5-1991).

Company: 0000870105

Cntr.pt.: 01	Bl.Prod T/day	Daily flow m3/day	Chloromethane mg/tonne	Chloroethylene mg/tonne	Bromomethane mg/tonne	Bromodichloromethane mg/tonne	Dichloromethane mg/tonne	1,1-Dichloroethane mg/tonne	1,2-Dichloroethane mg/tonne	1,1-Dichloroethylene mg/tonne
Jan/90	516	84,212	-	-	-	-	-	-	-	-
Feb/90	516	79,039	-	-	-	-	42,277	-	-	-
Mar/90	516	76,760	-	-	-	-	-	-	-	-
Apr/90	516	78,488	-	-	-	-	-	-	-	-
May/90	516	75,708	-	-	-	-	-	-	-	-
Jun/90	516	82,468	-	-	-	-	-	-	-	-

Company: 0000870105

Cntr.pt.: 01	Bl.Prod T/day	Daily flow m3/day	trans-1,2-Dichloroethylene mg/tonne	1,2-Dichloropropane mg/tonne	cis-1,3-Dichloropropylene mg/tonne	trans-1,3-Dichloropropylene mg/tonne	Dibromoethylene mg/tonne	Trichloromethane mg/tonne	Dibromochloromethane mg/tonne	Tribromomethane mg/tonne	1,1,2-Trichloroethane mg/tonne
Jan/90	516	84,212	-	-	-	-	-	196,462	-	-	-
Feb/90	516	79,039	-	-	-	-	-	108,908	-	-	-
Mar/90	516	76,760	-	-	-	-	-	57,421	-	-	-
Apr/90	516	78,488	-	-	-	-	-	72,860	-	-	-
May/90	516	75,708	-	-	-	-	-	65,731	-	-	-
Jun/90	516	82,468	-	-	-	-	-	119,868	-	-	-

Company: 0000870105

Cntr.pt.: 01	Bl.Prod T/day	Daily flow m3/day	Trichloroethylene mg/tonne	Trifluorochloromethane mg/tonne	Tetrachloromethane mg/tonne	1,1,2,2-Tetrachloroethane mg/tonne	Tetrachloroethylene mg/tonne	Chlorobenzene mg/tonne	1,2-Dichlorobenzene mg/tonne	1,3-Dichlorobenzene mg/tonne	1,4-Dichlorobenzene mg/tonne
Jan/90	516	84,212	-	-	-	-	-	-	-	-	-
Feb/90	516	79,039	-	-	-	-	-	-	-	-	-
Mar/90	516	76,760	-	-	-	-	-	-	-	-	-
Apr/90	516	78,488	-	-	-	-	-	-	-	-	-
May/90	516	75,708	-	-	-	-	-	-	-	-	-
Jun/90	516	82,468	-	-	-	-	-	400	-	-	-

Table 2b. Nonhalogenated volatiles (ATG17). Boise Cascade Canada Ltd. (Fort Frances). (Date: 8-5-1991).

Company: 0000870105

Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Styrene mg/tonne	Benzene mg/tonne	m,p-Xylene mg/tonne	o-Xylene mg/tonne	Toluene mg/tonne
Jan/90	924	84,212	-	-	109	-	3263
Feb/90	1,070	79,039	-	-	-	-	620
Mar/90	1,094	76,760	-	-	-	-	435
Apr/90	886	78,488	-	-	-	-	1867
May/90	935	75,708	162	324	81	-	1943
Jun/90	1,078	82,468	-	-	115	-	444

Table 9b. Inorganics (ATG 3, 4, 6, 7 & 15). Boise Cascade Canada Ltd. (Fort Frances). (Date: 8-5-1991).

Company: 0000870105

Cntr.pt.: 01 Date	Prod. T/day	Av. flow m3/day	pH	Conductivity µs/cm	NH3 + NH4 g/tonne	NO2+NO3 g/tonne	Total-N g/tonne	Total-P g/tonne	Sulphide g/tonne
Jan/90	852	77,853	6.9	1587	29	23	804	149	17
Feb/90	1,070	77,868	6.7	1662	18	19	533	141	16
Mar/90	1,094	76,111	6.8	1676	2	7	434	104	3
Apr/90	838	71,696	6.9	1620	1	16	847	145	19
May/90	891	77,617	6.6	1619	7	19	1152	175	9
Jun/90	1,078	82,558	6.8	1622	6	13	844	134	23

Table 10b. Group and unspecific variables (ATG 1, 5, 8, PP1-3). Boise Cascade Canada Ltd. (Fort Frances). (Date: 8-5-1991).

Company: 0000870105

Cntr.pt.: 01 Date	Prod. T/day	Bl.Prod T/day	Av. flow m3/tonne	BOD5 Kg/tonne	AOX Kg/tonne	COD Kg/tonne	DOC Kg/tonne	TOC Kg/tonne	TSS Kg/tonne	COD/AOX	COD/BOD
Jan/90	852	516	91.37	16.1	4.2	74.1	-	-	11.9	17.8	4.6
Feb/90	1,070	516	72.80	8.9	5.0	50.3	-	-	8.8	10.1	5.7
Mar/90	1,094	516	69.56	6.4	4.6	44.4	-	-	7.3	9.7	6.9
Apr/90	838	516	85.57	9.5	3.3	54.8	-	-	9.8	16.6	5.8
May/90	891	516	87.12	11.6	4.1	64.6	-	-	14.9	15.7	5.6
Jun/90	1,078	516	76.60	9.6	3.0	55.8	-	-	14.3	18.8	5.8

Table 3b. Extractable base neutrals (ATG19). Boise Cascade Canada Ltd. (Fort Frances). (Date: 8-5-1991).

Company: 0000870105

Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Naphthalene mg/tonne	1-Methyl-naphthalene mg/tonne	2-Methyl-naphthalene mg/tonne	1-Chloro-naphthalene mg/tonne	2-Chloro-naphthalene mg/tonne	Anthracene mg/tonne	Benz[a]-anthracene mg/tonne	Dibenz[a] anthracene mg/tonne
Jan/90	924	84,212	-	-	-	-	-	-	-	-
Feb/90	1,070	79,039	-	-	-	-	-	-	-	-
Mar/90	1,094	79,562	-	-	-	-	-	-	-	-
Apr/90	886	78,488	-	-	-	-	-	-	-	-
May/90	935	75,708	-	-	-	-	-	-	-	-
Jun/90	1,078	82,468	-	-	-	-	-	-	-	-

Company: 0000870105

Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Phenanthrene mg/tonne	Acenaphthene mg/tonne	Acenaphthylene mg/tonne	5-Nitro-acenaphthene mg/tonne	Chrysene mg/tonne	Fluoranthene mg/tonne	Benz[b]-fluoranthene mg/tonne	Benz[k] fluoranthene mg/tonne	Fluorene mg/tonne
Jan/90	924	84,212	-	-	-	-	-	-	-	-	-
Feb/90	1,070	79,039	-	-	-	-	-	-	-	-	-
Mar/90	1,094	79,562	-	-	-	-	-	-	-	-	-
Apr/90	886	78,488	-	-	-	-	-	-	-	-	-
May/90	935	75,708	-	-	-	-	-	-	-	-	-
Jun/90	1,078	82,468	-	-	-	-	-	-	-	-	-

Company: 0000870105

Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Pyrene mg/tonne	Benz[a]-pyrene mg/tonne	ıdeno[1,2,3-cd pyrene mg/tonne	Perylene mg/tonne	Benz[g,h,i]-perylene mg/tonne	Indole mg/tonne	Camphene mg/tonne
Jan/90	924	84,212	-	-	-	-	-	-	7747
Feb/90	1,070	79,039	-	-	-	-	-	177	1551
Mar/90	1,094	79,562	-	-	-	-	-	-	596
Apr/90	886	78,488	-	-	-	-	-	-	762
May/90	935	75,708	-	-	-	-	-	-	1174
Jun/90	1,078	82,468	-	-	-	-	-	-	337

Table 4b. Acidic extractables (ATG20). Boise Cascade Canada Ltd. (Fort Frances). (Date: 8-5-1991).

Company: 0000870105

Cntr.pt.: 01 Date	Prod. T/day	Bl.Prod T/day	Daily flow m3/day	000 Phenol mg/tonne	m-Cresol mg/tonne	o-Cresol mg/tonne	p-Cresol mg/tonne	2,4-xylenol mg/tonne	4-Chloro-m-cresol mg/tonne	2-Chloro-phenol mg/tonne	2,4-Dichloro-phenol mg/tonne
Jan/90	852	516	84,212	-	-	-	-	-	-	-	636
Feb/90	1,070	516	79,039	-	2,069	-	961	-	-	-	-
Mar/90	1,094	516	79,562	-	400	873	-	349	-	-	1,249
Apr/90	838	516	78,488	-	-	749	-	-	-	-	608
May/90	891	516	75,708	-	-	1,015	-	-	-	44	792
Jun/90	1,078	516	82,468	-	-	712	-	-	-	-	559

Company: 0000870105

Cntr.pt.: 01 Date	Prod. T/day	Bl.Prod T/day	Daily flow m3/day	2,6-Dichloro-phenol mg/tonne	2,3,4-Tri-chlorophenol mg/tonne	2,3,5-Tri-chlorophenol mg/tonne	2,4,5-Tri-chlorophenol mg/tonne	2,4,6-Tri-chlorophenol mg/tonne	2,3,4,5-Tetra-chlorophenol mg/tonne	2,3,4,6-Tetra-chlorophenol mg/tonne	2,3,5,6-Tetra-chlorophenol mg/tonne
Jan/90	852	516	84,212	-	-	1,028	963	1,795	-	-	-
Feb/90	1,070	516	79,039	-	1,838	-	1,838	3,370	107	-	-
Mar/90	1,094	516	79,562	-	-	-	-	2,930	-	-	308
Apr/90	838	516	78,488	-	-	1,445	-	-	-	-	-
May/90	891	516	75,708	-	-	836	-	-	-	-	-
Jun/90	1,078	516	82,468	-	-	1,055	-	-	-	-	-

Company: 0000870105

Cntr.pt.: 01 Date	Prod. T/day	Bl.Prod T/day	Daily flow m3/day	Penta-chlorophenol mg/tonne	4-Nitro-phenol mg/tonne	2,4-Dinitro-phenol mg/tonne
Jan/90	852	516	84,212	-	-	-
Feb/90	1,070	516	79,039	-	-	-
Mar/90	1,094	516	79,562	-	-	-
Apr/90	838	516	78,488	-	-	-
May/90	891	516	75,708	-	-	-
Jun/90	1,078	516	82,468	-	-	26

Table 5b. Chlorinated, neutrals (ATG(23). Boise Cascade Canada Ltd. (Fort Frances). (Date: 8-5-1991).

Company: 0000870105 Cntr.pt.: 01	Bl.Prod T/day	Daily flow m3/day	Hexachloro-ethane mg/tonne	Hexachloro-butadiene mg/tonne	Hexachloro-yclopentadien mg/tonne	1,2,3-Trichloro benzene mg/tonne	1,2,4-Trichloro benzene mg/tonne	2,4,5-Trichloro toluene mg/tonne	1,2,3,4-Tetra-hlorobenzene mg/tonne	1,2,3,5-Tetra-chlorobenzene mg/tonne
Date										
Jan/90	516	84,212	13.1	-	17.3	135.5	70.5	15.7	38.5	-
Feb/90	516	79,039	21.8	11.9	52.7	94.1	24.8	165.4	20.2	-
Mar/90	516	79,562	-	-	5.2	469.7	-	37.3	-	-
Apr/90	516	78,488	-	-	2.3	68.8	-	15.7	-	-
May/90	516	75,708	-	1.5	1.5	-	-	-	-	-
Jun/90	516	82,468	-	-	-	-	-	132.5	-	17.7

Company: 0000870105 Cntr.pt.: 01	Bl.Prod T/day	Daily flow m3/day	1,2,4,5-Tetra-chlorobenzene mg/tonne	Penta-chlorobenzene mg/tonne	Hexa-chlorobenzene mg/tonne	Octachloro-styrene mg/tonne
Date						
Jan/90	516	84,212	-	13.7	41.5	3.9
Feb/90	516	79,039	-	105.4	22.4	-
Mar/90	516	79,562	-	-	-	-
Apr/90	516	78,488	17.5	33.0	14.6	6.2
May/90	516	75,708	-	18.5	-	-
Jun/90	516	82,468	8.0	-	-	16.8

Table 6b. Chlorinated dioxins, dibenzofuranes and PCB's (ATG(23). Boise Cascade Canada Ltd. (Fort Frances).

Company: 0000870105 Cntr.pt.: 01	Bl.Prod T/day	Daily flow m3/day	2,3,7,8-TCDD µgtonne	Total TCDD µgtonne	Total TCDF µgtonne	Total PCDD µgtonne	Total PCDF µgtonne	Total HxCDD µgtonne	Total HxCDF µgtonne	Total HpCDD µgtonne
Date										
Jan/90	516	84,212	-	-	-	-	-	-	-	-
Feb/90	516	79,039	-	-	-	-	-	-	-	-
Mar/90	516	79,562	-	-	8.2	-	-	-	-	-
Apr/90	516	78,488	-	-	14.8	-	-	-	-	-
May/90	516	75,708	-	-	67.5	-	-	-	-	-
Jun/90	516	82,468	-	-	32.0	-	-	-	-	-

Company: 0000870105 Cntr.pt.: 01	Bl.Prod T/day	Daily flow m3/day	Total HpCDF µg/tonne	OCDD µg/tonne	OCDF µg/tonne	Total PCB's µg/tonne
Date						
Jan/90	516	84,212	-	-	-	-
Feb/90	516	79,039	-	-	-	-
Mar/90	516	79,562	-	-	-	-
Apr/90	516	78,488	-	-	-	-
May/90	516	75,708	-	4.7	-	-
Jun/90	516	82,468	-	6.9	-	-

Table 7b. Fatty and resin acids (ATG 26). Boise Cascade Canada Ltd. (Fort Frances). (Date: 8-5-1991).

Company: 0000870105 Cntr.pt.: 01	Prod. T/day	Bl.Prod T/day	0.0 Daily flow m3/day	Oleic acid g/tonne	Pimaric acid g/tonne	Abietic acid g/tonne	Dehydro-abietic acid g/tonne	Isopimaric acid g/tonne	Levopimaric acid g/tonne	Neoabietic acid g/tonne
Date										
Jan/90	852	516	84212.0	0.6	1.7	1.0	7019.0	2.1	0.5	0.5
Feb/90	1,070	516	79039.0	1.3	0.8	-	3.7	1.5	0.6	-
Mar/90	1,094	516	79562.0	6.5	3.8	-	22.3	2.9	-	0.8
Apr/90	838	516	78488.0	27.4	2.1	-	45.8	1.9	-	-
May/90	891	516	75708.0	24.0	15.7	14.0	24.7	31.3	-	0.9
Jun/90	1,078	516	82468.0	18.7	7.9	0.6	19.3	8.5	2.6	0.7

Company: 0000870105 Cntr.pt.: 01	Prod. T/day	Bl.Prod T/day	Daily flow m3/day	Chlorodehydro abietic acid g/tonne	ichlorodehydr abietic acid g/tonne	Total resin acids g/tonne	Total resin acids Kg/day	Total resin acids mg/l
Date								
Jan/90	852	516	84212.0	-	3360.0	7024.7	5985	71.07
Feb/90	1,070	516	79039.0	4.0	2.8	8.5	9	0.11
Mar/90	1,094	516	79562.0	11.7	22.2	35.3	39	0.49
Apr/90	838	516	78488.0	20.8	26.3	62.6	52	0.67
May/90	891	516	75708.0	39.9	29.9	109.7	98	1.29
Jun/90	1,078	516	82468.0	11.3	24.1	45.0	49	0.59

Values for dehydroabietic acid and dichlorodehydroabietic acid are monthly averages

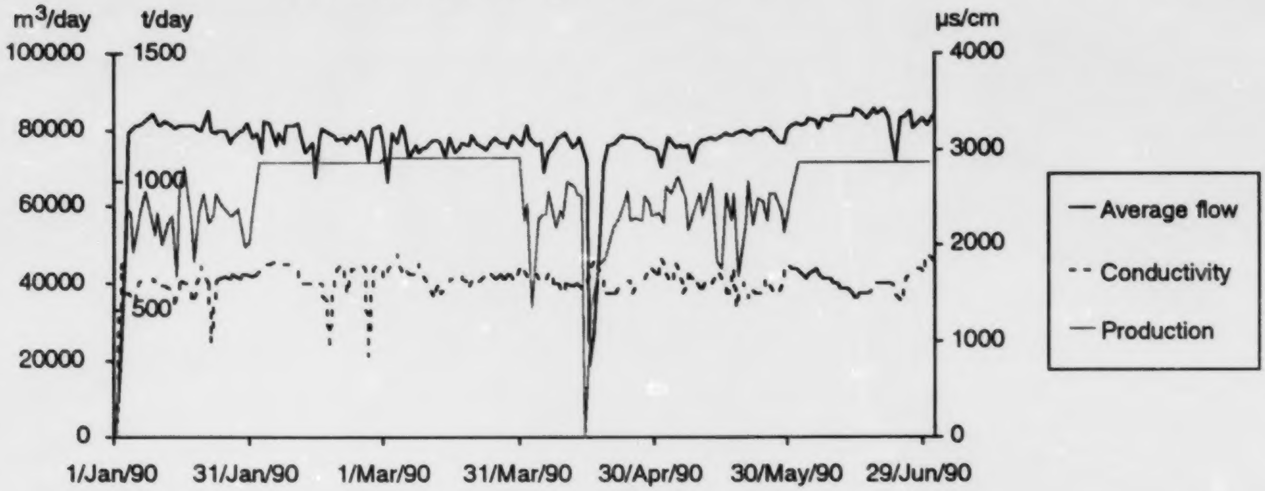
Table 6b. Metals (ATG 9 &12). Boise Cascade Canada Ltd. (Fort Frances). (Date: 6-5-1991).

Company 00008701C	Prod. T/day	Daily flow m3/day	Berylium g/tonne	Aluminium g/tonne	Copper g/tonne	Zink g/tonne	Chromium g/tonne	Nickel g/tonne	Molybdenum g/tonne	Cobalt g/tonne
Date										
Jan/90	852	84,212	-	109	1.2	15.1	-	-	-	-
Feb/90	1,070	79,039	-	107	1.9	13.1	0.7	-	1.5	-
Mar/90	1,094	79,562	-	68	1.5	13.1	0.4	-	1.4	-
Apr/90	838	78,488	0.19	70	2.3	13.7	0.8	0.9	1.4	-
May/90	891	75,708	0.46	107	2.2	15.6	1.3	0.8	1.5	-
Jun/90	1,078	82,468	0.15	111	1.8	14.0	0.7	-	1.6	-

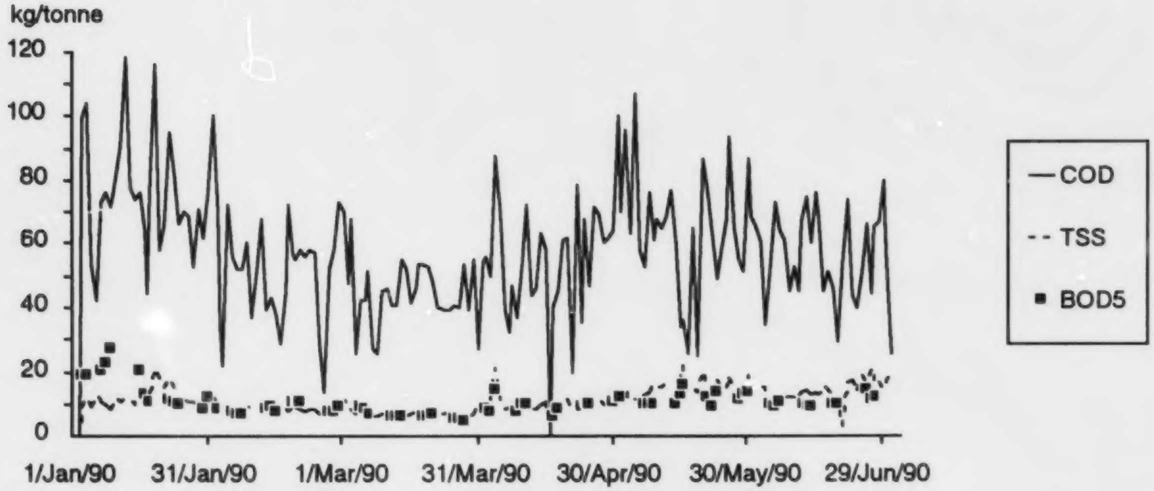
Company 00008701C	Prod. T/day	Daily flow m3/day	Vanadium g/tonne	Silver g/tonne	Lead g/tonne	Cadmium g/tonne	Thallium g/tonne	Mercury g/tonne
Date								
Jan/90	852	84,212	-	-	-	-	-	-
Feb/90	1,070	79,039	-	0.3	-	0.15	2.22	-
Mar/90	1,094	79,562	0.4	-	-	-	2.18	0.00
Apr/90	838	78,488	0.4	-	-	-	1.87	0.00
May/90	891	75,708	0.4	-	-	-	2.55	-
Jun/90	1,078	82,468	0.4	-	-	-	2.30	-

Values for aluminium and zink are monthly averages.

Average flow, Production and Conductivity data from Boise Cascade Canada Ltd. (Fort Frances), Control point 0100 (12-5-1991).



TSS, COD and BOD5 data from Boise Cascade Canada Ltd. (Fort Frances), Control point 0100 (12-5-1991).



Bl. Production and AOX data from Boise Cascade Canada Ltd. (Fort Frances), Control point 0100 (17-5-1991).

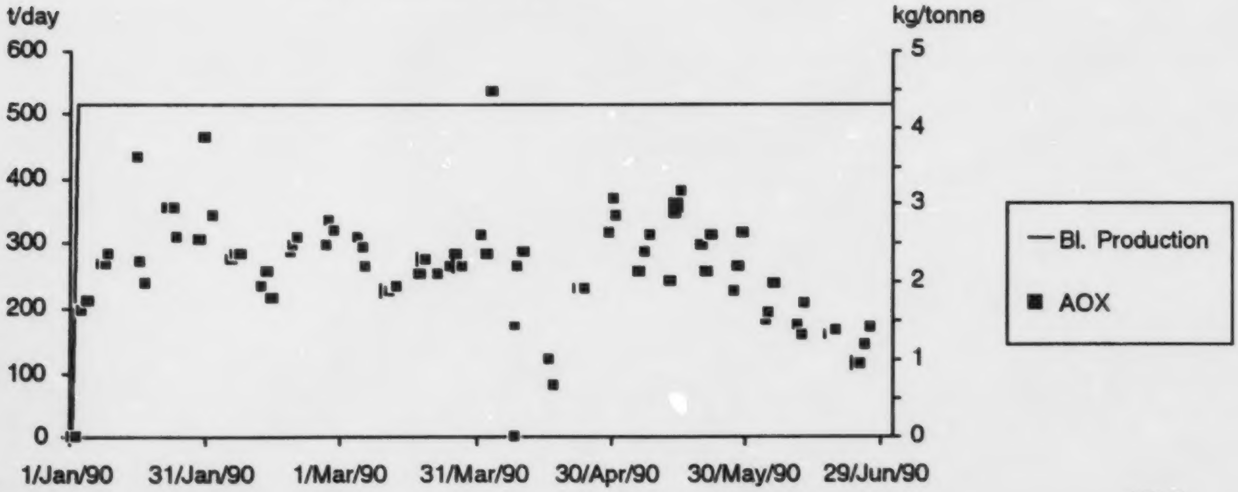


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Table 1b. Halogenated volatiles (ATG16). Canadian Pacific Forest Products (Dryden). (Date: 3-5-1991).

Company: 0000840108 Cntr.pt.: 01	Bl. prod. T/day	Daily flow m3/day	Chloro-methane mg/tonne	Chloro-ethylene mg/tonne	Bromo-methane mg/tonne	Bromodi-chloromethane mg/tonne	Dichloro-methane mg/tonne	1,1-Dichloro-ethane mg/tonne	1,2-Dichloro-ethane mg/tonne	1,1-Dichloro-ethylene mg/tonne
Jan/90	626	95,000	-	-	-	-	15,390	-	-	-
Feb/90	841	95,000	-	-	-	-	1,807	-	-	-
Mar/90	0	60,000	-	-	-	-	-	-	-	-
Apr/90	890	84,000	-	-	-	-	-	-	-	-
May/90	1,043	100,000	-	-	-	-	-	-	-	-
Jun/90	844	106,000	-	-	-	829	-	-	-	-

Company: 0000840108 Cntr.pt.: 01	Bl. prod. T/day	Daily flow m3/day	trans-1,2-Di-chloroethylene mg/tonne	1,2-Dichloro-propane mg/tonne	cis-1,3-Di-chloropropylen mg/tonne	trans-1,3-Di-chloropropylen mg/tonne	Dibromo-ethylene mg/tonne	Trichloro-methane mg/tonne	Dibromo-chloromethane mg/tonne	Tribromo-methane mg/tonne	1,1,2-Tri-chloroethane mg/tonne
Jan/90	626	95,000	-	-	-	-	-	42,188	-	-	-
Feb/90	841	95,000	-	-	-	-	-	23,157	-	-	-
Mar/90	0	60,000	-	-	-	-	-	-	-	-	-
Apr/90	890	84,000	-	-	-	-	-	12,175	-	-	-
May/90	1,043	100,000	-	-	-	-	-	9,243	-	-	-
Jun/90	844	106,000	-	-	-	-	-	8,741	-	-	-

Company: 0000840108 Cntr.pt.: 01	Bl. prod. T/day	Daily flow m3/day	Trichloro-ethylene mg/tonne	Trifluoro-chloromethane mg/tonne	Tetrachloro-methane mg/tonne	1,1,2,2-Tetra-chloroethane mg/tonne	Tetrachloro-ethylene mg/tonne	Chloro-benzene mg/tonne	1,2-Dichloro-benzene mg/tonne	1,3-Dichloro-benzene mg/tonne	1,4-Dichloro-benzene mg/tonne
Jan/90	626	95,000	-	-	-	-	-	-	-	-	-
Feb/90	841	95,000	-	-	-	-	-	-	-	-	-
Mar/90	0	60,000	-	-	-	-	-	-	-	-	-
Apr/90	890	84,000	-	-	-	-	-	-	-	-	-
May/90	1,043	100,000	-	-	-	-	-	-	-	-	-
Jun/90	844	106,000	-	-	-	-	-	-	289	-	-

Table 2b. Nonhalogenated volatiles (ATG17). Canadian Pacific Forest Products (Dryden). (Date: 3-5-1991).

Company: 0000840108 Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	Styrene mg/tonne	Benzene mg/tonne	m,p-Xylene mg/tonne	o-Xylene mg/tonne	Toluene mg/tonne
Date							
Jan/90	847	95,000	-	-	426	-	763
Feb/90	943	95,000	-	-	-	-	-
Mar/90	607	60,000	-	-	-	-	-
Apr/90	943	84,000	-	-	-	-	-
May/90	1,196	100,000	-	-	-	-	1054
Jun/90	630	106,000	-	-	185	454	-

Table 9b. Inorganics (ATG 3, 4, 6, 7 & 15). Canadian Pacific Forest Products (Dryden). (Date: 3-5-1991).

Company: 0000840108 Cntr.pt.: 01	Prod. T/day	Av. flow m3/day	pH	Conductivity µs/cm	NH3 + NH4 g/tonne	NO2+NO3 g/tonne	Total-N g/tonne	Total-P g/tonne	Sulphide g/tonne
Date									
Jan/90	1,115	92,871	7.2	2055	110	42	126	150	2
Feb/90	1,006	91,571	7.2	2057	32	46	131	178	7
Mar/90	833	81,161	7.3	1952	41	49	157	200	8
Apr/90	940	92,733	7.1	1742	35	175	163	158	5
May/90	926	92,548	7.0	1829	70	313	224	220	-
Jun/90	975	99,633	7.3	1622	236	138	333	225	3

Table 10b. Group and unspecific variables (ATG 1, 5, 8, PP1-3). Canadian Pacific Forest Products (Dryden). (Date: 3-5-1991).

Company: 0000840108 Cntr.pt.: 01	Prod. T/day	Bl.Prod T/day	Av. flow m3/tonne	BOD5 Kg/tonne	AOX Kg/tonne	COD Kg/tonne	DOC Kg/tonne	TOC Kg/tonne	TSS Kg/tonne	COD/AOX	COD/BOD
Date											
Jan/90	1,115	850	83.26	2.9	3.4	50.6	-	-	4.9	14.7	17.7
Feb/90	1,006	744	91.04	3.0	3.3	51.0	-	-	4.6	15.2	17.2
Mar/90	833	574	97.43	2.9	3.7	52.4	-	-	5.2	14.1	18.2
Apr/90	940	792	98.63	3.3	2.7	59.0	-	-	6.5	21.9	17.8
May/90	926	808	99.99	3.7	2.7	65.5	-	-	6.7	24.6	17.8
Jun/90	975	848	102.17	3.9	2.5	56.3	-	-	6.5	22.9	14.3

Table 3b. Extractable base neutrals (ATG19). Canadian Pacific Forest Products (Dryden). (Date: 3-5-1991).

Company: 0000840108 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Naphthalene mg/tonne	1-Methyl-naphthalene mg/tonne	2-Methyl-naphthalene mg/tonne	1-Chloro-naphthalene mg/tonne	2-Chloro-naphthalene mg/tonne	Anthracene mg/tonne	Benz[a]-anthracene mg/tonne	Dibenz[a] anthracene mg/tonne
Jan/90	847	95,000	-	-	-	-	-	-	-	-
Feb/90	943	95,000	-	-	-	-	-	-	-	-
Mar/90	607	92,000	-	-	-	-	-	-	-	-
Apr/90	943	84,000	-	-	-	-	-	-	-	-
May/90	1,196	102,000	136	-	-	-	-	-	-	-
Jun/90	630	106,000	-	-	-	-	-	-	-	-

Company: 0000840108 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Phenanthrene mg/tonne	Acenaphthene mg/tonne	Acenaphthylene mg/tonne	5-Nitro-acenaphthene mg/tonne	Chrysene mg/tonne	Fluoranthene mg/tonne	Benz[b]-fluoranthene mg/tonne	Benz[k] fluoranthene mg/tonne	Fluorene mg/tonne
Jan/90	847	95,000	-	-	-	-	-	-	-	-	-
Feb/90	943	95,000	-	-	-	-	-	-	-	-	-
Mar/90	607	92,000	-	-	-	-	-	-	-	-	-
Apr/90	943	84,000	-	-	-	-	-	-	-	-	-
May/90	1,196	102,000	-	-	-	-	-	-	-	-	-
Jun/90	630	106,000	-	-	-	-	-	-	-	-	-

Company: 0000840108 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Pyrene mg/tonne	Benz[a]-pyrene mg/tonne	ideno[1,2,3-cd pyrene mg/tonne	Perylene mg/tonne	Benz[g,h,i]-perylene mg/tonne	Indole mg/tonne	Camphene mg/tonne
Jan/90	847	95,000	-	-	-	-	-	-	-
Feb/90	943	95,000	-	-	-	-	-	-	-
Mar/90	607	92,000	-	-	-	-	-	-	-
Apr/90	943	84,000	-	-	-	-	-	-	-
May/90	1,196	102,000	-	-	-	-	-	-	-
Jun/90	630	106,000	-	-	-	-	-	-	-

Table 4b. Acidic extractables (ATG20). Canadian Pacific Forest Products (Dryden). (Date: 3-5-1991).

Company: 0000840108 Cntr.pt.: 01 Date	Prod. T/day	Bl.Prod T/day	Daily flow m3/day	000 Phenol mg/tonne	m-Cresol mg/tonne	o-Cresol mg/tonne	p-Cresol mg/tonne	2,4-xylenol mg/tonne	4-Chloro-m-cresol mg/tonne	2-Chloro-phenol mg/tonne	2,4-Dichloro-phenol mg/tonne
Jan/90	847	626	95,000	-	-	-	-	-	-	-	-
Feb/90	943	841	95,000	-	111	-	-	-	-	-	474
Mar/90	607	765	92,000	-	121	258	-	-	-	-	589
Apr/90	943	815	84,000	-	-	107	-	-	-	-	340
May/90	1,196	807	102,000	-	17	320	-	-	-	-	822
Jun/90	630	844	106,000	-	-	328	-	-	-	-	465

Company: 0000840108 Cntr.pt.: 01 Date	Prod. T/day	Bl.Prod T/day	Daily flow m3/day	2,6-Dichloro-phenol mg/tonne	2,3,4-Tri-chlorophenol mg/tonne	2,3,5-Tri-chlorophenol mg/tonne	2,4,5-Tri-chlorophenol mg/tonne	2,4,6-Tri-chlorophenol mg/tonne	2,3,4,5-Tetra-chlorophenol mg/tonne	2,3,4,6-Tetra-chlorophenol mg/tonne	2,3,5,6-Tetra-chlorophenol mg/tonne
Jan/90	847	626	95,000	-	-	-	1,472	2,853	-	-	-
Feb/90	943	841	95,000	-	3,163	-	-	-	-	-	-
Mar/90	607	765	92,000	-	-	-	-	3,247	204	-	-
Apr/90	943	815	84,000	-	-	1,443	-	-	41	-	134
May/90	1,196	807	102,000	-	-	2,503	-	-	-	-	253
Jun/90	630	844	106,000	-	-	1,382	-	-	-	-	-

Company: 0000840108 Cntr.pt.: 01 Date	Prod. T/day	Bl.Prod T/day	Daily flow m3/day	Penta-chlorophenol mg/tonne	4-Nitro-phenol mg/tonne	2,4-Dinitro-phenol mg/tonne
Jan/90	847	626	95,000	-	-	-
Feb/90	943	841	95,000	-	-	-
Mar/90	607	765	92,000	241	-	216
Apr/90	943	815	84,000	-	-	-
May/90	1,196	807	102,000	152	228	-
Jun/90	630	844	106,000	-	-	-

Table 5b. Chlorinated, neutrals (ATG(23). Canadian Pacific Forest Products (Dryden). (Date: 3-5-1991).

Company: 0000840108 Cntr.pt.: 01 Date	Bl.Prod T/day	Daily flow m3/day	Hexachloro-ethane mg/tonne	Hexachloro-butadiene mg/tonne	Hexachloro-yclopentadien mg/tonne	1,2,3-Trichloro benzene mg/tonne	1,2,4-Trichloro benzene mg/tonne	2,4,5-Trichloro toluene mg/tonne	1,2,3,4-Tetra-chlorobenzene mg/tonne	1,2,3,5-Tetra-chlorobenzene mg/tonne
Jan/90	626	95,000	14.9	17.0	17.3	61.3	33.4	-	-	-
Feb/90	841	95,000	8.8	9.0	-	40.7	35.2	-	5.9	-
Mar/90	765	92,000	-	-	-	70.7	-	31.3	-	-
Apr/90	815	84,000	-	-	-	118.2	-	19.6	2.8	36.2
May/90	807	102,000	-	3.0	4.6	142.8	-	102.4	3.3	126.6
Jun/90	844	106,000	-	-	-	158.1	-	106.4	-	-

Company: 0000840108 Cntr.pt.: 01 Date	Bl.Prod T/day	Daily flow m3/day	1,2,4,5-Tetra-chlorobenzene mg/tonne	Penta-chlorobenzene mg/tonne	Hexa-chlorobenzene mg/tonne	Octachloro-styrene mg/tonne
Jan/90	626	95,000	-	44.6	335.7	4.6
Feb/90	841	95,000	-	82.9	143.9	7.5
Mar/90	765	92,000	-	17.8	-	-
Apr/90	815	84,000	13.3	3.7	-	-
May/90	807	102,000	22.2	-	-	-
Jun/90	844	106,000	3.6	-	77.2	124.2

Table 6b. Chlorinated dioxins, dibenzofuranes and PCB's (ATG(23). Canadian Pacific Forest Products (Dryden). (Date: 3-5-1991).

Company: 0000840108 Cntr.pt.: 01 Date	Bl.Prod T/day	Daily flow m3/day	2,3,7,8-TCDD µgtonne	Total TCDD µgtonne	Total TCDF µgtonne	Total PCDD µgtonne	Total PCDF µgtonne	Total HxCDD µgtonne	Total HxCDF µgtonne	Total HpCDD µgtonne
Jan/90	626	95,000	-	-	-	-	-	-	-	-
Feb/90	841	95,000	-	-	-	-	-	-	-	-
Mar/90	765	92,000	-	-	2.2	-	-	-	-	-
May/90	807	102,000	-	-	24.0	-	-	-	-	-
Jun/90	844	106,000	-	-	12.6	-	-	-	-	-
			-	-	-	-	-	-	-	-

Company: 0000840108 Cntr.pt.: 01 Date	Bl.Prod T/day	Daily flow m3/day	Total HpCDF µg/tonne	OCDD µg/tonne	OCDF µg/tonne	Total PCB's µg/tonne
Jan/90	414	95,000	-	-	-	59.7
Feb/90	428	95,000	-	-	-	-
Mar/90	330	92,000	-	-	-	-
May/90	575	102,000	-	-	-	-
Jun/90	395	106,000	-	-	-	-

Table 7b. Fatty and resin acids (ATG 26). Canadian Pacific Forest Products (Dryden). (Date: 3-5-1991).

Company: 0000840108 Cntr.pt.: 01 Date	Prod. T/day	Bl.Prod T/day	Daily flow m3/day	Oleic acid g/tonne	Pimaric acid g/tonne	Abietic acid g/tonne	Dehydro-abietic acid g/tonne	Isopimaric acid g/tonne	Levopimaric acid g/tonne	Neoabietic acid g/tonne
Jan/90	847	626	95,000	9.6	1.8	3.6	5.8	2.4	-	1.0
Feb/90	943	841	95,000	1.1	1.8	-	4.3	0.5	0.6	1.0
Mar/90	607	765	92,000	6.4	3.9	2.3	3.1	2.3	-	1.8
Apr/90	943	815	84,000	11.6	-	-	4.3	-	-	5.0
May/90	1,196	807	102,000	-	-	12.1	3.1	3.1	-	-
Jun/90	630	844	106,000	29.4	1.2	5.6	4.9	2.0	1.0	1.7

Company: 0000840108 Cntr.pt.: 01 Date	Prod. T/day	Bl.Prod T/day	Daily flow m3/day	Chlorodehydro- abietic acid g/tonne	ichlorodehydr abietic acid g/tonne	Total resin acids g/tonne	Total resin acids Kg/day	Total resin acids mg/l
Jan/90	847	626	95,000	1.4	22.3	15.5	13	0.14
Feb/90	943	841	95,000	2.3	13.8	10.2	10	0.10
Mar/90	607	765	92,000	9.9	10.2	25.8	16	0.17
Apr/90	943	815	84,000	10.2	14.2	18.1	17	0.20
May/90	1,196	807	102,000	29.1	9.0	37.9	45	0.44
Jun/90	630	844	106,000	4.5	4.5	22.4	14	0.13

Values for dehydroabietic acid and dichlorodehydroabietic acid are monthly averages

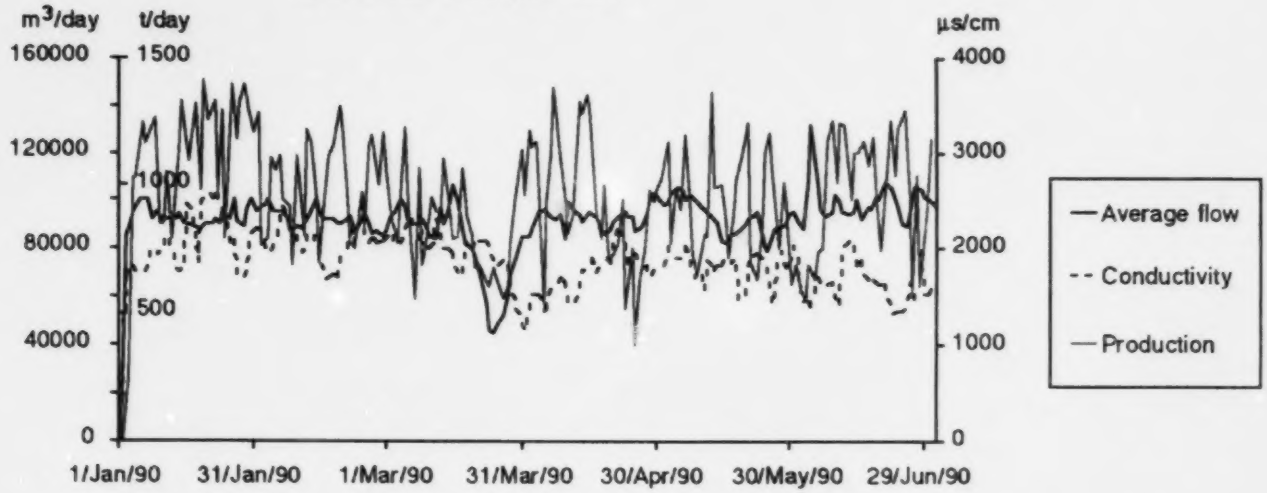
Table 8b. Metals (ATG 9 &12). Canadian Pacific Forest Products (Dryden). (Date: 3-5-1991).

Company 00008401C	Prod T/day	Daily flow m3/day	Beryllium g/tonne	Aluminium g/tonne	Copper g/tonne	Zinc g/tonne	Chromium g/tonne	Nickel g/tonne	Molybdenum g/tonne	Cobalt g/tonne
Date										
Jan/90	847	95,000	-	117	-	10.8	-	-	2.2	-
Feb/90	943	95,000	-	100	-	8.0	-	-	-	-
Mar/90	607	92,000	-	165	-	17.0	-	-	3.7	-
Apr/90	943	84,000	0.27	118	0.6	10.8	-	-	1.9	-
May/90	1,196	102,000	0.20	84	0.5	8.1	-	-	1.8	-
Jun/90	630	106,000	0.24	304	2.0	19.0	-	2.4	4.5	-

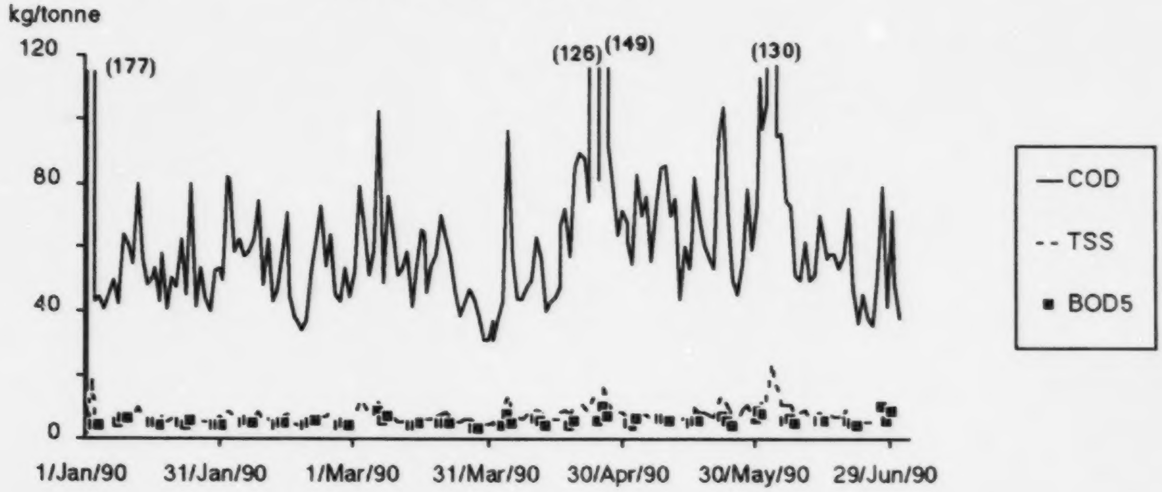
Company 00008401C	Prod T/day	Daily flow m3/day	Vanadium g/tonne	Silver g/tonne	Lead g/tonne	Cadmium g/tonne	Thallium g/tonne	Mercury g/tonne
Date								
Jan/90	847	95,000	-	-	-	-	-	-
Feb/90	943	95,000	-	0.6	-	-	4.03	-
Mar/90	607	92,000	0.5	0.9	-	-	6.06	0.01
Apr/90	943	84,000	-	-	-	-	2.67	-
May/90	1,196	102,000	0.1	-	0.9	-	3.41	-
Jun/90	630	106,000	0.7	-	2.0	-	3.37	-

Values for aluminium and zink are monthly averages

Average flow, Production and Conductivity data from Canadian Pacific Forest Products (Dryden), Control point 0100 (12-5-1991).



TSS, COD and BOD5 data from Canadian Pacific Forest Products (Dryden), Control point 0100 (12-5-1991).



BL. Production and AOX data from Canadian Pacific Forest Products (Dryden), Control point 0100 (12-5-1991).

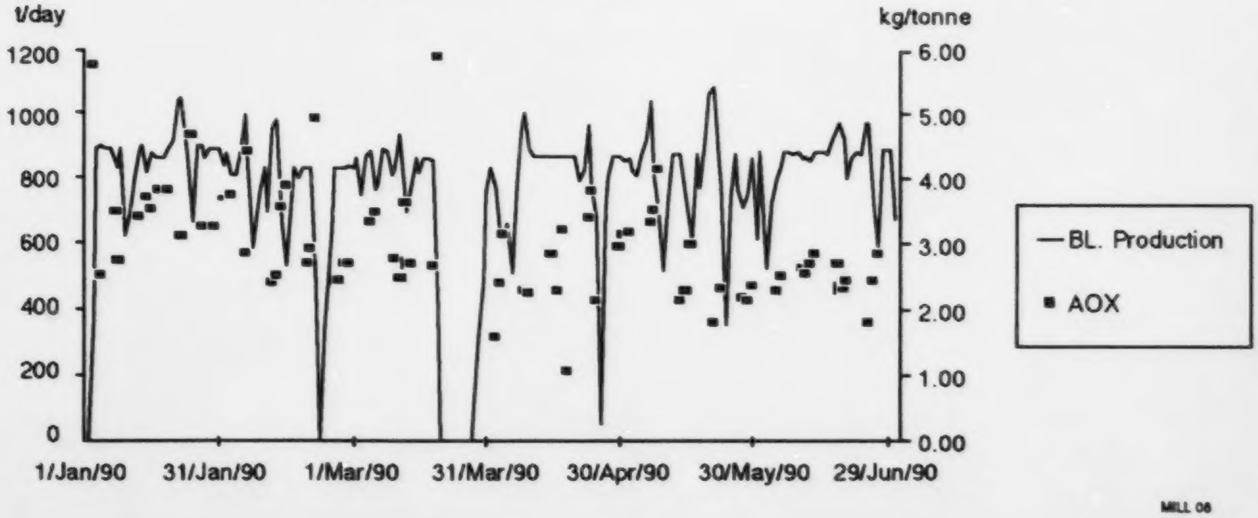


Table 1b. Halogenated volatiles (ATG16). Canadian Pacific Forest Products (Thunder Bay).. (Date: 8-5-1991).

Company: 0000840009 Cntr.pt.: 01	Bl.Prod T/day	Daily flow m3/day	Chloro-methane mg/tonne	Chloro-ethylene mg/tonne	Bromo-methane mg/tonne	Bromodi-chloromethane mg/tonne	Dichloro-methane mg/tonne	1,1-Dichloro-ethane mg/tonne	1,2-Dichloro-ethane mg/tonne	1,1-Dichloro-ethylene mg/tonne
Jan/90	1,100	174,000	-	-	-	-	-	-	-	-
Feb/90	1,100	175,000	-	-	-	-	-	-	-	445
Mar/90	1,100	160,000	-	-	-	179	-	-	-	-
Apr/90	1,100	190,000	-	-	-	-	-	-	-	-
May/90	1,100	180,000	-	-	-	-	-	-	-	-
Jun/90	1,100	189,881	-	-	-	-	-	-	-	-

Company: 0000840009 Cntr.pt.: 01	Bl.Prod T/day	Daily flow m3/day	trans-1,2-Di-chloroethylene mg/tonne	1,2-Dichloro-propane mg/tonne	cis-1,3-Di-chloropropylene mg/tonne	trans-1,3-Di-chloropropylene mg/tonne	Dibromo-ethylene mg/tonne	Trichloro-methane mg/tonne	Dibromo-chloromethane mg/tonne	Tribromo-methane mg/tonne	1,1,2-Tri-chloroethane mg/tonne
Jan/90	1,100	174,000	-	-	-	-	-	278,020	-	-	-
Feb/90	1,100	175,000	-	-	-	-	-	232,273	-	-	-
Mar/90	1,100	160,000	-	-	-	-	-	203,636	-	-	-
Apr/90	1,100	190,000	-	-	-	-	-	191,727	-	-	-
May/90	1,100	180,000	-	-	-	-	-	177,382	-	-	-
Jun/90	1,100	189,881	-	-	-	-	-	279,125	-	-	-

Company: 0000840009 Cntr.pt.: 01	Bl.Prod T/day	Daily flow m3/day	Trichloro-ethylene mg/tonne	Trifluoro-chloromethane mg/tonne	Tetrachloro-methane mg/tonne	1,1,2,2-Tetra-chloroethane mg/tonne	Tetrachloro-ethylene mg/tonne	Chloro-benzene mg/tonne	1,2-Dichloro-benzene mg/tonne	1,3-Dichloro-benzene mg/tonne	1,4-Dichloro-benzene mg/tonne
Jan/90	1,100	174,000	-	-	-	-	-	-	-	-	-
Feb/90	1,100	175,000	-	-	-	684	-	-	-	-	-
Mar/90	1,100	160,000	-	-	-	-	-	-	-	-	-
Apr/90	1,100	190,000	-	-	-	-	-	-	-	-	-
May/90	1,100	180,000	-	-	-	-	-	-	-	-	-
Jun/90	1,100	189,881	-	-	-	-	-	-	-	-	-

Table 2b. Nonhalogenated volatiles (ATG17). Canadian Pacific Forest Products (Thunder Bay).. (Date: 8-5-1991

Company: 0000840009

Date	Cntr.pt.: 01 Prod. T/day	Daily flow m3/day	Styrene mg/tonne	Benzene mg/tonne	m,p-Xylene mg/tonne	o-Xylene mg/tonne	Toluene mg/tonne
Jan/90	2,442	174,000	-	-	413	-	36
Feb/90	2,138	175,000	-	-	-	-	-
Mar/90	2,191	160,000	-	-	-	-	-
Apr/90	2,533	190,000	-	-	-	-	-
May/90	1,776	180,000	-	-	-	-	-
Jun/90	2,266	189,881	-	-	-	-	-

Table 9b. Inorganics (ATG 3, 4, 6, 7 & 15). Canadian Pacific Forest Products (Thunder Bay).. (Date: 8-5-1991

Company: 0000840009

Date	Cntr.pt.: 01 Prod. T/day	Av. flow m3/day	pH	Conductivity µs/cm	NH3 + NH4 g/tonne	NO2+NO3 g/tonne	Total-N g/tonne	Total-P g/tonne	Sulphide g/tonne
Jan/90	2,262	165,484	6.9	1604	20	15	113	48	4
Feb/90	2,348	175,679	6.9	1773	19	15	87	62	16
Mar/90	2,144	164,516	6.6	1763	2	5	128	60	18
Apr/90	2,112	169,000	6.6	1430	4	5	122	50	6
May/90	2,707	183,226	6.5	1460	2	4	107	38	13
Jun/90	2,244	186,083	6.6	1538	6	5	121	43	5

Table 10b. Group and unspecific variables (ATG 1, 5, 8, PP1-3). Canadian Pacific Forest Products (Thunder Bay).. (Date: 8-5-1991)

Company: 0000840009

Date	Cntr.pt.: 01 Prod. T/day	Bl.Prod T/day	Av. flow m3/tonne	BOD5 Kg/tonne	AOX Kg/tonne	COD Kg/tonne	DOC Kg/tonne	TOC Kg/tonne	TSS Kg/tonne	COD/AOX	COD/BOD
Jan/90	2,442	1,100	67.77	20.3	4.0	72.4	-	-	6.0	18	3.6
Feb/90	2,138	1,100	82.17	26.8	5.4	93.3	-	-	7.4	17	3.5
Mar/90	2,231	1,100	73.74	20.5	4.1	67.9	-	-	6.1	17	3.3
Apr/90	2,533	1,100	66.72	17.1	2.6	60.6	-	-	7.6	23	3.5
May/90	1,776	1,100	103.17	28.3	3.2	100.5	-	-	9.6	31	3.6
Jun/90	2,266	1,100	82.12	21.9	3.7	76.4	-	-	7.1	21	3.5

Table 3b. Extractable base neutrals (ATG19). Canadian Pacific Forest Products (Thunder Bay).. (Date: 8-5-199

Company: 0000840009
Cntr.pt.: 01

Date	Prod. T/day	Daily flow m3/day	Naphthalene mg/tonne	1-Methyl-naphthalene mg/tonne	2-Methyl-naphthalene mg/tonne	1-Chloro-naphthalene mg/tonne	2-Chloro-naphthalene mg/tonne	Anthracene mg/tonne	Benz[a]-anthracene mg/tonne	Dibenz[a] anthracene mg/tonne
Jan/90	2,442	174,000	-	-	-	-	-	-	-	-
Feb/90	2,138	175,000	123	-	41	-	-	-	-	-
Mar/90	2,231	170,000	114	-	-	-	-	-	-	-
Apr/90	2,533	190,000	-	-	-	-	-	-	-	-
May/90	1,776	180,000	253	-	-	-	-	-	-	-
Jun/90	2,266	189,881	-	-	-	-	-	-	-	-

Company: 0000840009
Cntr.pt.: 01

Date	Prod. T/day	Daily flow m3/day	Phenan-threne mg/tonne	Acenaph-thene mg/tonne	Acenaph-thylene mg/tonne	5-Nitro-ace-naphthene mg/tonne	Chrysene mg/tonne	Fluor-anthene mg/tonne	Benz[b]-fluoranthene mg/tonne	Benz[k] fluoranthene mg/tonne	Fluorene mg/tonne
Jan/90	2,442	174,000	-	-	-	-	-	-	-	-	-
Feb/90	2,138	175,000	-	-	-	-	-	-	-	-	-
Mar/90	2,231	170,000	30	61	-	-	-	-	-	-	-
Apr/90	2,533	190,000	-	-	-	-	-	-	-	-	-
May/90	1,776	180,000	51	-	-	-	-	20	-	-	-
Jun/90	2,266	189,881	-	-	-	-	-	-	-	-	-

Company: 0000840009
Cntr.pt.: 01

Date	Prod. T/day	Daily flow m3/day	Pyrene mg/tonne	Benz[a]-pyrene mg/tonne	ideno[1,2,3-cd pyrene mg/tonne	Perylene mg/tonne	Benz[g,h,i]-perylene mg/tonne	Indole mg/tonne	Camphene mg/tonne
Jan/90	2,442	174,000	-	-	-	-	-	-	705
Feb/90	2,138	175,000	-	-	-	-	-	-	-
Mar/90	2,231	170,000	-	-	-	-	-	91	251
Apr/90	2,533	190,000	-	-	-	-	-	-	45
May/90	1,776	180,000	-	-	-	-	-	-	2331
Jun/90	2,266	189,881	-	-	-	-	-	-	-

Table 4b. Acidic extractables (ATG20). Canadian Pacific Forest Products (Thunder Bay).. (Date: 8-5-1991).

Company: 0000840009
Cntr.pt.: 01

Date	Prod. T/day	Bl.Prod T/day	Daily flow m3/day	000 Phenol mg/tonne	m-Cresol mg/tonne	o-Cresol mg/tonne	p-Cresol mg/tonne	2,4-xylenol mg/tonne	4-Chloro-m-cresol mg/tonne	2-Chloro-phenol mg/tonne	2,4-Dichloro-phenol mg/tonne
Jan/90	2,442	1,100	174,000	1,140	-	-	-	-	-	-	316
Feb/90	2,138	1,100	175,000	647	74	-	-	-	-	-	636
Mar/90	2,231	1,100	170,000	8,915	6,020	-	-	-	-	-	1,051
Apr/90	2,533	1,100	190,000	-	23	-	30	-	-	-	691
May/90	1,776	1,100	180,000	2,579	-	-	-	-	-	74	458
Jun/90	2,266	1,100	189,881	1,144	-	184	-	293	-	-	794

Company: 0000840009
Cntr.pt.: 01

Date	Prod. T/day	Bl.Prod T/day	Daily flow m3/day	2,6-Dichloro-phenol mg/tonne	2,3,4-Tri-chlorophenol mg/tonne	2,3,5-Tri-chlorophenol mg/tonne	2,4,5-Tri-chlorophenol mg/tonne	2,4,6-Tri-chlorophenol mg/tonne	2,3,4,5-Tetra-chlorophenol mg/tonne	2,3,4,6-Tetra-chlorophenol mg/tonne	2,3,5,6-Tetra-chlorophenol mg/tonne
Jan/90	2,442	1,100	174,000	-	-	870	807	1,550	-	-	-
Feb/90	2,138	1,100	175,000	-	-	-	-	-	-	-	-
Mar/90	2,231	1,100	170,000	-	-	-	-	2,164	93	-	-
Apr/90	2,533	1,100	190,000	-	-	-	-	760	-	-	-
May/90	1,776	1,100	180,000	-	-	507	-	-	65	-	-
Jun/90	2,266	1,100	189,881	-	-	1,433	-	-	-	-	-

Company: 0000840009
Cntr.pt.: 01

Date	Prod. T/day	Bl.Prod T/day	Daily flow m3/day	Penta-chlorophenol mg/tonne	4-Nitro-phenol mg/tonne	2,4-Dinitro-phenol mg/tonne
Jan/90	2,442	1,100	174,000	-	-	-
Feb/90	2,138	1,100	175,000	-	-	-
Mar/90	2,231	1,100	170,000	-	-	-
Apr/90	2,533	1,100	190,000	-	-	-
May/90	1,776	1,100	180,000	-	-	-
Jun/90	2,266	1,100	189,881	-	-	-

Table 5b. Chlorinated, neutrals (ATG(23). Canadian Pacific Forest Products (Thunder Bay).. (Date: 8-5-1991).

Company: 0000840009 Cntr.pt.: 01	Bl.Prod T/day	Daily flow m3/day	Hexachloro-ethane mg/tonne	Hexachloro-butadiene mg/tonne	Hexachloro-yclopentadien mg/tonne	1,2,3-Trichloro-benzene mg/tonne	1,2,4-Trichloro-benzene mg/tonne	2,4,5-Trichloro-toluene mg/tonne	1,2,3,4-Tetra-chlorobenzene mg/tonne	1,2,3,5-Tetra-chlorobenzene mg/tonne
Date										
Jan/90	1,100	174,000	16.8	25.3	23.4	130.3	86.7	222.4	59.2	-
Feb/90	1,100	175,000	21.6	12.7	6.4	102.1	155.9	78.0	23.2	-
Mar/90	1,100	170,000	-	2.0	2.0	-	-	-	-	-
Apr/90	1,100	190,000	6.6	-	-	-	-	218.5	-	-
May/90	1,100	180,000	-	-	-	-	-	-	-	-
Jun/90	1,100	189,881	3.1	-	-	81.1	-	-	-	-

Company: 0000840009 Cntr.pt.: 01	Bl.Prod T/day	Daily flow m3/day	1,2,4,5-Tetra-chlorobenzene mg/tonne	Penta-chlorobenzene mg/tonne	Hexa-chlorobenzene mg/tonne	Octachloro-styrene mg/tonne
Date						
Jan/90	1,100	174,000	-	135.4	213.5	9.5
Feb/90	1,100	175,000	-	200.5	94.8	7.3
Mar/90	1,100	170,000	-	-	-	-
Apr/90	1,100	190,000	51.8	-	43.7	16.2
May/90	1,100	180,000	-	76.3	20.8	4.1
Jun/90	1,100	189,881	40.6	-	124.1	19.3

Table 6b. Chlorinated dioxine, dibenzofuranes and PCB's (ATG(24). Canadian Pacific Forest Products (Thunder Bay).. (Date: 8-5-1991).

Company: 0000840009 Cntr.pt.: 01	Bl.Prod T/day	Daily flow m3/day	2,3,7,8-TCDD µgtonne	Total TCDD µgtonne	Total TCDF µgtonne	Total PCDD µgtonne	Total PCDF µgtonne	Total HxCDD µgtonne	Total HxCDF µgtonne	Total HpCDD µgtonne
Date										
Jan/90	1,100	174,000	-	-	-	-	-	-	-	-
Feb/90	1,100	175,000	-	-	-	-	-	-	-	-
Mar/90	1,100	170,000	-	-	3.9	-	-	-	-	-
Mar/90	1,100	160,000	-	-	3.6	-	-	-	-	-
Apr/90	1,100	190,000	-	-	22.5	-	-	-	-	-
May/90	1,100	180,000	-	-	13.9	-	-	-	-	-

Company: 0000840009 Cntr.pt.: 01	Bl.Prod T/day	Daily flow m3/day	Total HpCDF µg/tonne	OCDD µg/tonne	OCDF µg/tonne	Total PCB's µg/tonne
Date						
Jan/90	1,100	174,000	-	150.3	13.9	-
Feb/90	1,100	175,000	-	15.6	-	-
Mar/90	1,100	170,000	-	-	-	-
Mar/90	1,100	160,000	-	-	-	-
Apr/90	1,100	190,000	-	-	-	-
May/90	1,100	180,000	-	34.4	-	-

Table 7b. Fatty and resin acids (ATG 26). Canadian Pacific Forest Products (Thunder Bay).. (Date: 8-5-1991).

Company: 0000840009 Cntr.pt.: 01	Prod. T/day	Bl.Prod T/day	Daily flow m3/day	Oleic acid g/tonne	Pimaric acid g/tonne	Abietic acid g/tonne	Dehydro-abietic acid g/tonne	Isopimaric acid g/tonne	Levopimaric acid g/tonne	Neoabietic acid g/tonne
Date										
Jan/90	2,442	1,100	174,000	-	-	-	172.5	-	-	-
Feb/90	2,138	1,100	175,000	3.7	2.5	7.2	125.5	5.2	2.5	6.0
Mar/90	2,231	1,100	170,000	32.8	16.3	2.1	91.2	68.7	-	-
Apr/90	2,533	1,100	190,000	21.6	-	-	113.4	-	-	-
May/90	1,776	1,100	180,000	44.0	41.9	224.2	207.5	254.9	-	58.5
Jun/90	2,266	1,100	189,881	-	-	-	127.4	-	-	-

Company: 0000840009 Cntr.pt.: 01	Prod. T/day	Bl.Prod T/day	Daily flow m3/day	Chlorodehydro-abietic acid g/tonne	ichlorodehydr abietic acid g/tonne	Total resin acids g/tonne	Total resin acids Kg/day	Total resin acids mg/l
Date								
Jan/90	2,442	1,100	174,000	-	8.6	172.5	421	2.42
Feb/90	2,138	1,100	175,000	14.0	8.1	156.2	334	1.91
Mar/90	2,231	1,100	170,000	26.4	8.5	191.3	427	2.51
Apr/90	2,533	1,100	190,000	140.6	8.4	174.5	442	2.33
May/90	1,776	1,100	180,000	87.2	9.2	840.9	1493	8.30
Jun/90	2,266	1,100	189,881	-	8.1	127.4	289	1.52

Values for dehydroabietic acid and dichlorodehydroabietic acid are monthly averages

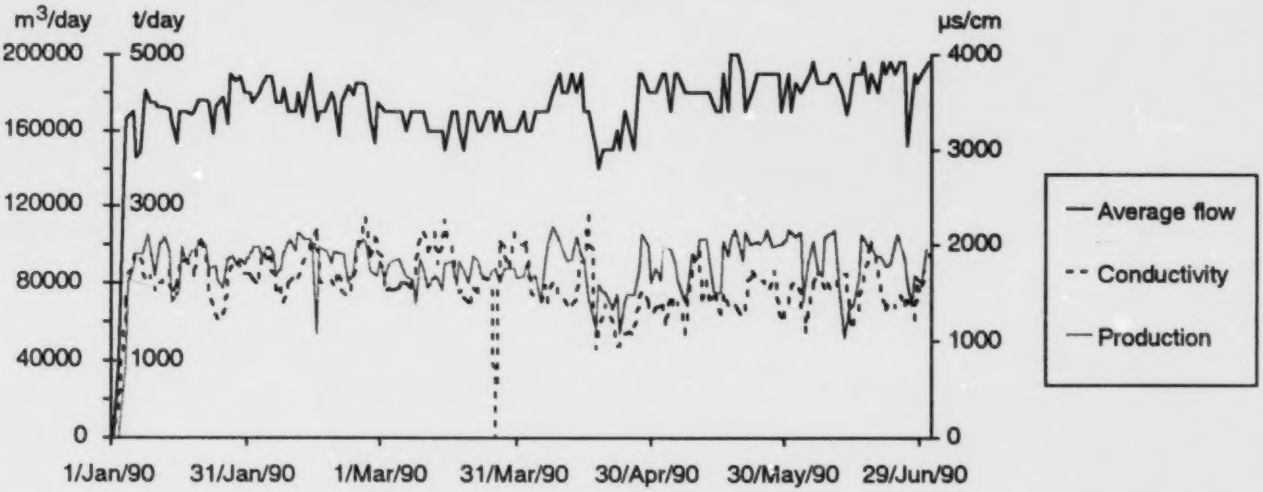
Table 8b. Metals (ATG 9 &12). Canadian Pacific Forest Products (Thunder Bay).. (Date: 9-5-1991).

Company 00008400C	Prod. T/day	Daily flow m3/day	Berylium g/tonne	Aluminium g/tonne	Copper g/tonne	Zinc g/tonne	Chromium g/tonne	Nickel g/tonne	Molybdenum g/tonne	Cobalt g/tonne
Date										
Jan/90	2,442	174,000	-	319	3.0	13.2	5.0	-	-	-
Feb/90	2,138	175,000	-	380	2.1	20.0	7.2	-	-	-
Mar/90	2,231	170,000	-	375	1.3	18.8	6.0	-	0.9	-
Apr/90	2,533	190,000	0.33	367	1.4	8.3	6.9	0.5	0.9	0.2
May/90	1,776	180,000	-	611	1.9	10.6	7.6	-	0.8	-
Jun/90	2,266	189,881	-	469	2.3	13.3	6.8	0.8	0.6	-

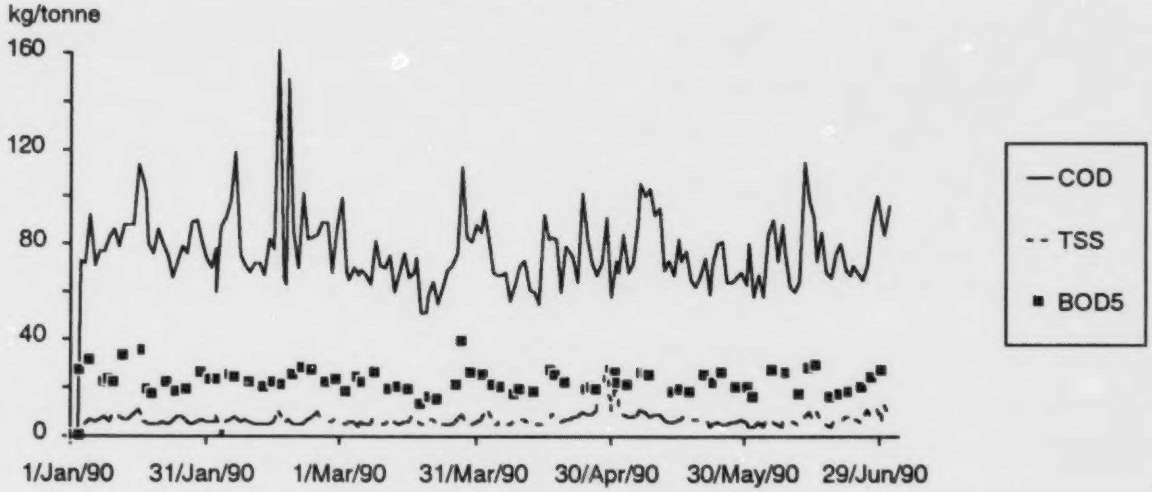
Company 00008400C	Prod. T/day	Daily flow m3/day	Vanadium g/tonne	Silver g/tonne	Lead g/tonne	Cadmium g/tonne	Thallium g/tonne	Mercury g/tonne
Date								
Jan/90	2,442	174,000	-	-	-	0.14	1.78	-
Feb/90	2,138	175,000	-	0.4	-	-	1.64	-
Mar/90	2,231	170,000	0.4	-	-	-	-	0.00
Apr/90	2,533	190,000	0.5	-	-	0.15	-	-
May/90	1,776	180,000	0.5	-	-	-	-	0.00
Jun/90	2,266	189,881	0.3	-	-	-	-	-

Values for aluminium and zink are monthly averages.

Average flow, Production and Conductivity data from Canadian Pacific Forest Products (Thunder Bay), Control point 0100 (13-5-1991).



TSS, COD and BOD5 data from Canadian Pacific Forest Products (Thunder Bay)., Control point 0100 (13-5-1991).



Bl. Production and AOX data from Canadian Pacific Forest Products (Thunder Bay)., Control point 0100 (13-5-1991).

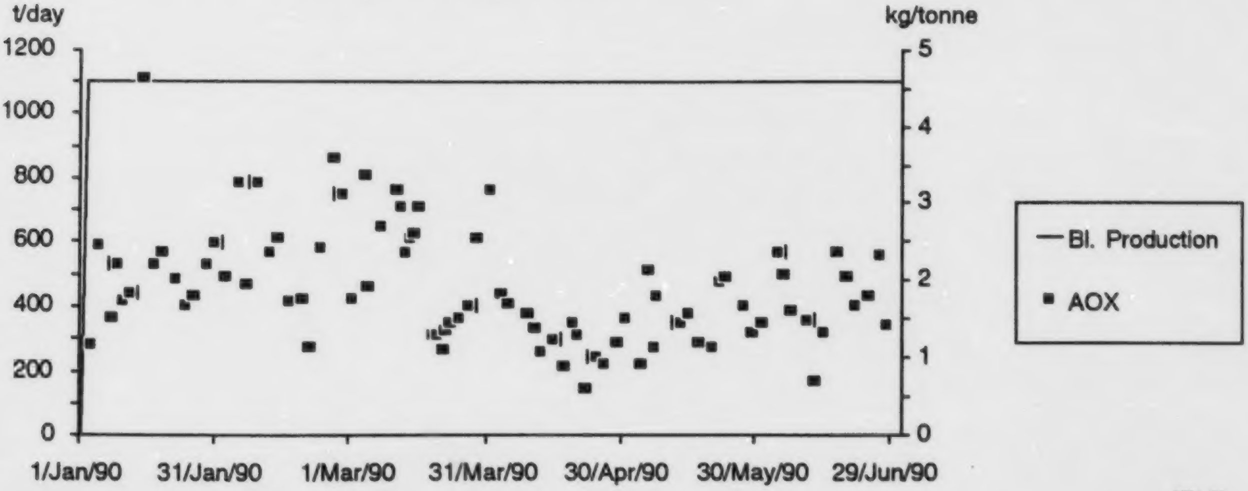


Table 1b. Halogenated volatiles (ATG16). Domtar Inc., Fine Papers Division (Cornwall). (Date: 18-5-1991).

Company: 0000140301

Cntr.pt.: 01	Bl.Prod T/day	Daily flow m3/day	Chloro-methane mg/tonne	Chloro-ethylene mg/tonne	Bromo-methane mg/tonne	Bromodi-chloromethane mg/tonne	Dichloro-methane mg/tonne	1,1-Dichloro-ethane mg/tonne	1,2-Dichloro-ethane mg/tonne	1,1-Dichloro-ethylene mg/tonne
Jan/90	425	128,000	-	-	-	542	-	-	-	-
Feb/90	447	125,000	-	-	-	-	-	-	-	-
Mar/90	373	122,000	-	-	-	-	-	-	-	-
Apr/90	445	138,000	-	-	-	-	-	-	-	-
May/90	379	119,000	-	-	-	1,162	-	-	-	-
Jun/90	445	134,000	-	-	-	-	-	-	-	-

Company: 0000140301

Cntr.pt.: 01	Bl.Prod T/day	Daily flow m3/day	trans-1,2-Di-chloroethylene mg/tonne	1,2-Dichloro-propane mg/tonne	cis-1,3-Di-chloropropylen mg/tonne	trans-1,3-Di-chloropropylen mg/tonne	Dibromo-ethylene mg/tonne	Trichloro-methane mg/tonne	Dibromo-chloromethane mg/tonne	Tribromo-methane mg/tonne	1,1,2-Tri-chloroethane mg/tonne
Jan/90	425	128,000	-	-	-	-	-	66,861	-	-	-
Feb/90	447	125,000	-	-	-	-	-	60,045	-	-	-
Mar/90	373	122,000	-	-	-	-	-	44,810	-	-	-
Apr/90	445	138,000	-	-	-	-	-	77,528	-	-	-
May/90	379	119,000	-	-	-	-	-	109,580	-	-	-
Jun/90	445	134,000	-	-	-	-	-	73,775	-	-	-

Company: 0000140301

Cntr.pt.: 01	Bl.Prod T/day	Daily flow m3/day	Trichloro-ethylene mg/tonne	Trifluoro-chloromethane mg/tonne	Tetrachloro-methane mg/tonne	1,1,2,2-Tetra-chloroethane mg/tonne	Tetrachloro-ethylene mg/tonne	Chloro-benzene mg/tonne	1,2-Dichloro-benzene mg/tonne	1,3-Dichloro-benzene mg/tonne	1,4-Dichloro-benzene mg/tonne
Jan/90	425	128,000	-	-	-	-	-	-	-	-	-
Feb/90	447	125,000	-	-	-	-	-	-	-	-	-
Mar/90	373	122,000	-	-	-	-	-	-	-	-	-
Apr/90	445	138,000	-	-	-	-	-	-	-	-	-
May/90	379	119,000	-	-	-	-	-	-	-	-	-
Jun/90	445	134,000	-	-	-	-	-	-	-	-	-

Table 2b. Nonhalogenated volatiles (ATG17). Domtar Inc., Fine Papers Division (Cornwall). (Date: 18-5-1991).

Company: 0000140301

Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	Styrene mg/tonne	Benzene mg/tonne	m,p-Xylene mg/tonne	o-Xylene mg/tonne	Toluene mg/tonne
Date							
Jan/90	768	128,000	683	2083	-	-	867
Feb/90	838	125,000	451	946	-	-	510
Mar/90	742	122,000	674	822	-	-	707
Apr/90	502	138,000	1210	1210	-	-	1622
May/90	679	119,000	859	1735	-	-	1420
Jun/90	811	134,000	-	1570	-	-	1107

Table 9b. Inorganics (ATG 3, 4, 6, 7 & 15). Domtar Inc., Fine Papers Division (Cornwall). (Date: 18-5-1991).

Company: 0000140301

Cntr.pt.: 01	Prod. T/day	Av. flow m3/day	pH	Conductivity µs/cm	NH3 + NH4 g/tonne	NO2+NO3 g/tonne	Total-N g/tonne	Total-P g/tonne	Sulphide g/tonne
Date									
Jan/90	705	125,100	7.9	1184	98	16	408	38	169
Feb/90	715	122,786	7.4	1207	17	45	223	69	54
Mar/90	754	128,000	7.0	1090	192	93	679	51	18
Apr/90	724	119,533	6.4	940	155	23	429	83	4
May/90	724	124,871	7.0	1105	166	5	517	52	18
Jun/90	735	131,560	6.8	1117	25	9	663	54	47

Table 10b. Group and unspecific variables (ATG 1, 5, 8, PP1-3). Domtar Inc., Fine Papers Division (Cornwall). (Date: 18-5-1991).

Company: 0000140301

Cntr.pt.: 01	Prod. T/day	Bl.Prod T/day	Av. flow m3/tonne	BOD5 Kg/tonne	AOX Kg/tonne	COD Kg/tonne	DOC Kg/tonne	TOC Kg/tonne	TSS Kg/tonne	COD/AOX	COD/BOD
Date											
Jan/90	705	410	177.45	36.4	1.1	109.3	0.0	-	15.7	103	3.0
Feb/90	715	385	171.84	32.3	0.9	100.8	-	-	15.3	109	3.1
Mar/90	754	439	169.66	28.0	1.0	79.7	-	-	13.6	82	2.8
Apr/90	724	381	165.16	26.1	0.7	70.1	-	-	12.0	101	2.7
May/90	724	421	172.48	27.1	0.9	80.8	-	-	11.5	88	3.0
Jun/90	735	433	179.09	30.4	1.1	82.8	-	-	16.1	72	2.7

Table 3b. Extractable base neutrals (ATG19). Domtar Inc., Fine Papers Division (Cornwall). (Date: 18-5-1991)

Company: 0000140301 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Naphthalene mg/tonne	1-Methyl-naphthalene mg/tonne	2-Methyl-naphthalene mg/tonne	1-Chloro-naphthalene mg/tonne	2-Chloro-naphthalene mg/tonne	Anthracene mg/tonne	Benz[a]-anthracene mg/tonne	Dibenz[a] anthracene mg/tonne
Jan/90	768	128,000	1433	-	-	-	-	267	150	-
Feb/90	838	122,000	786	-	-	-	-	-	-	-
Mar/90	742	122,000	-	-	-	-	-	-	-	-
Apr/90	502	138,000	-	-	-	-	-	-	-	-
May/90	679	119,000	1016	-	-	-	-	-	-	-
Jun/90	811	134,000	-	-	-	-	-	-	-	-

Company: 0000140301 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Phenanthrene mg/tonne	Acenaphthene mg/tonne	Acenaphthylene mg/tonne	5-Nitro-acenaphthene mg/tonne	Chrysene mg/tonne	Fluoranthene mg/tonne	Benz[b]-fluoranthene mg/tonne	Benz[k] fluoranthene mg/tonne	Fluorene mg/tonne
Jan/90	768	128,000	2183	-	633	-	183	1500	-	-	-
Feb/90	838	122,000	699	-	320	-	-	160	-	-	-
Mar/90	742	122,000	-	-	-	-	-	-	-	-	-
Apr/90	502	138,000	797	-	-	-	-	-	-	-	-
May/90	679	119,000	3137	-	-	-	298	841	-	-	-
Jun/90	811	134,000	3288	-	892	-	-	793	-	-	-

Company: 0000140301 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Pyrene mg/tonne	Benz[a]-pyrene mg/tonne	ıdeno[1,2,3-cd pyrene mg/tonne	Perylene mg/tonne	Benz[g,h,i]-perylene mg/tonne	Indole mg/tonne	Camphene mg/tonne
Jan/90	768	128,000	1100	-	-	-	-	933	-
Feb/90	838	122,000	102	-	-	-	-	-	-
Mar/90	742	122,000	-	-	-	-	-	-	-
Apr/90	502	138,000	-	-	-	-	-	-	-
May/90	679	119,000	491	-	-	-	-	-	-
Jun/90	811	134,000	413	-	-	-	-	-	-

Table 4b. Acidic extractables (ATG20). Domtar Inc., Fine Papers Division (Cornwall). (Date: 18-5-1991).

Company: 0000140301 Cntr.pt.: 01 Date	Prod. T/day	Bl.Prod T/day	Daily flow m3/day	Phenol mg/tonne	m-Cresol mg/tonne	o-Cresol mg/tonne	p-Cresol mg/tonne	2,4-xylenol mg/tonne	4-Chloro-m-cresol mg/tonne	2-Chloro-phenol mg/tonne	2,4-Dichloro-phenol mg/tonne
Jan/90	705	425	128,000	33,770	-	1,489	-	-	-	-	-
Feb/90	715	447	122,000	18,781	-	-	-	-	-	-	-
Mar/90	754	373	122,000	18,111	-	-	-	-	-	-	-
Apr/90	724	445	138,000	27,647	-	-	-	-	-	-	-
May/90	724	379	119,000	3,222	-	-	-	-	-	-	-
Jun/90	735	445	134,000	13,973	-	1,058	-	-	-	-	-

Company: 0000140301 Cntr.pt.: 01 Date	Prod. T/day	Bl.Prod T/day	Daily flow m3/day	2,6-Dichloro-phenol mg/tonne	2,3,4-Tri-chlorophenol mg/tonne	2,3,5-Tri-chlorophenol mg/tonne	2,4,5-Tri-chlorophenol mg/tonne	2,4,6-Tri-chlorophenol mg/tonne	2,3,4,5-Tetra-chlorophenol mg/tonne	2,3,4,6-Tetra-chlorophenol mg/tonne	2,3,5,6-Tetra-chlorophenol mg/tonne
Jan/90	705	425	128,000	-	-	-	-	-	-	-	-
Feb/90	715	447	122,000	-	-	-	-	-	-	-	-
Mar/90	754	373	122,000	-	-	-	-	-	-	-	-
Apr/90	724	445	138,000	-	-	-	-	-	-	-	-
May/90	724	379	119,000	-	-	-	-	-	-	-	-
Jun/90	735	445	134,000	-	-	-	-	-	-	-	-

Company: 0000140301 Cntr.pt.: 01 Date	Prod. T/day	Bl.Prod T/day	Daily flow m3/day	Penta-chlorophenol mg/tonne	4-Nitro-phenol mg/tonne	2,4-Dinitro-phenol mg/tonne
Jan/90	705	425	128,000	-	-	-
Feb/90	715	447	122,000	-	-	-
Mar/90	754	373	122,000	-	-	-
Apr/90	724	445	138,000	-	-	-
May/90	724	379	119,000	-	-	-
Jun/90	735	445	134,000	-	-	-

Table 5b. Chlorinated, neutrals (ATG(23). Domtar Inc., Fine Papers Division (Cornwall). (Date: 18-5-1991).

Company: 0000140301 Cntr.pt.: 01	Bl.Prod T/day	Daily flow m3/day	Hexachloro-ethane mg/tonne	Hexachloro-butadiene mg/tonne	Hexachloro-yclopentadien mg/tonne	1,2,3-Trichloro-benzene mg/tonne	1,2,4-Trichloro-benzene mg/tonne	2,4,5-Trichloro-toluene mg/tonne	1,2,3,4-Tetra-chlorobenzene mg/tonne	1,2,3,5-Tetra-chlorobenzene mg/tonne
Date										
Jan/90	425	128,000	-	-	-	-	2.1	-	-	-
Feb/90	447	125,000	-	-	-	-	-	-	-	-
Mar/90	373	122,000	-	-	-	-	2.3	-	-	-
Apr/90	445	138,000	-	-	-	-	-	-	-	-
May/90	379	119,000	-	-	-	-	-	-	-	-
Jun/90	445	134,000	-	-	-	-	-	-	-	-

Company: 0000140301 Cntr.pt.: 01	Bl.Prod T/day	Daily flow m3/day	1,2,4,5-Tetra-chlorobenzene mg/tonne	Penta-chlorobenzene mg/tonne	Hexa-chlorobenzene mg/tonne	Octachloro-styrene mg/tonne
Date						
Jan/90	425	128,000	-	-	-	-
Feb/90	447	125,000	-	-	-	-
Mar/90	373	122,000	-	-	-	-
Apr/90	445	138,000	-	-	-	-
May/90	379	119,000	-	-	-	-
Jun/90	445	134,000	-	-	-	-

Table 6b. Chlorinated dioxins, dibenzofuranes and PCB's (ATG(23). Domtar Inc., Fine Papers Division (Cornwall). (Date: 18-5-1991).

Company: 0000140301 Cntr.pt.: 01	Bl.Prod T/day	Daily flow m3/day	2,3,7,8-TCDD µgtonne	Total TCDD µgtonne	Total TCDF µgtonne	Total PCDD µgtonne	Total PCDF µgtonne	Total HxCDD µgtonne	Total HxCDF µgtonne	Total HpCDD µgtonne
Date										
Jan/90	425	128,000	-	-	7.5	-	-	-	-	-
Feb/90	447	125,000	-	-	8.2	-	-	-	-	-
Mar/90	373	122,000	-	-	13.4	-	-	-	-	-
Apr/90	445	138,000	-	-	2.8	-	-	-	-	15.8
May/90	379	119,000	-	-	4.7	-	-	-	-	-
Jun/90	445	134,000	-	-	29.8	-	-	-	-	-

Company: 0000140301 Cntr.pt.: 01	Bl.Prod T/day	Daily flow m3/day	Total HpCDF µg/tonne	OCDD µg/tonne	OCDF µg/tonne	Total PCB's µg/tonne
Date						
Jan/90	817	128,000	-	26.8	-	-
Feb/90	-	125,000	-	32.8	-	-
Mar/90	-	122,000	-	67.1	-	-
Apr/90	-	138,000	-	114.7	-	-
May/90	-	119,000	-	31.1	-	-
Jun/90	-	134,000	-	72.3	-	-

Table 7b. Fatty and resin acids (ATG 26). Domtar Inc., Fine Papers Division (Cornwall). (Date: 18-5-1991).

Company: 0000140301 Cntr.pt.: 01	Prod. T/day	Bl.Prod T/day	Daily flow m3/day	Oleic acid g/tonne	Pimaric acid g/tonne	Abietic acid g/tonne	Dehydro-abietic acid g/tonne	Isopimaric acid g/tonne	Levopimaric acid g/tonne	Neoabietic acid g/tonne
Date										
Jan/90	705	425	128,000	3.6	2.2	47.2	64.4	1.8	-	11.4
Feb/90	715	447	122,000	1.2	-	18.4	71.8	-	-	4.1
Mar/90	754	373	122,000	20.1	-	15.5	89.9	1.3	-	-
Apr/90	724	445	138,000	28.6	1.0	49.2	79.7	1.9	-	13.7
May/90	724	379	119,000	3.1	0.8	10.0	72.8	-	1.5	7.4
Jun/90	735	445	134,000	11.1	1.8	40.7	94.2	1.8	-	18.8

Company: 0000140301 Cntr.pt.: 01	Prod. T/day	Bl.Prod T/day	Daily flow m3/day	Chlorodehydro-abietic acid g/tonne	ichlorodehydr abietic acid g/tonne	Total resin acids g/tonne	Total resin acids Kg/day	Total resin acids mg/l
Date								
Jan/90	705	425	128,000	14.2	8.2	136	96	0.75
Feb/90	715	447	122,000	2.7	8.1	96	69	0.56
Mar/90	754	373	122,000	8.5	3.9	111	84	0.69
Apr/90	724	445	138,000	12.4	2.4	153	111	0.80
May/90	724	379	119,000	9.7	2.4	98	71	0.59
Jun/90	735	445	134,000	25.6	4.3	173	127	0.95

Values for dehydroabietic acid and dichlorodehydroabietic acid are monthly averages

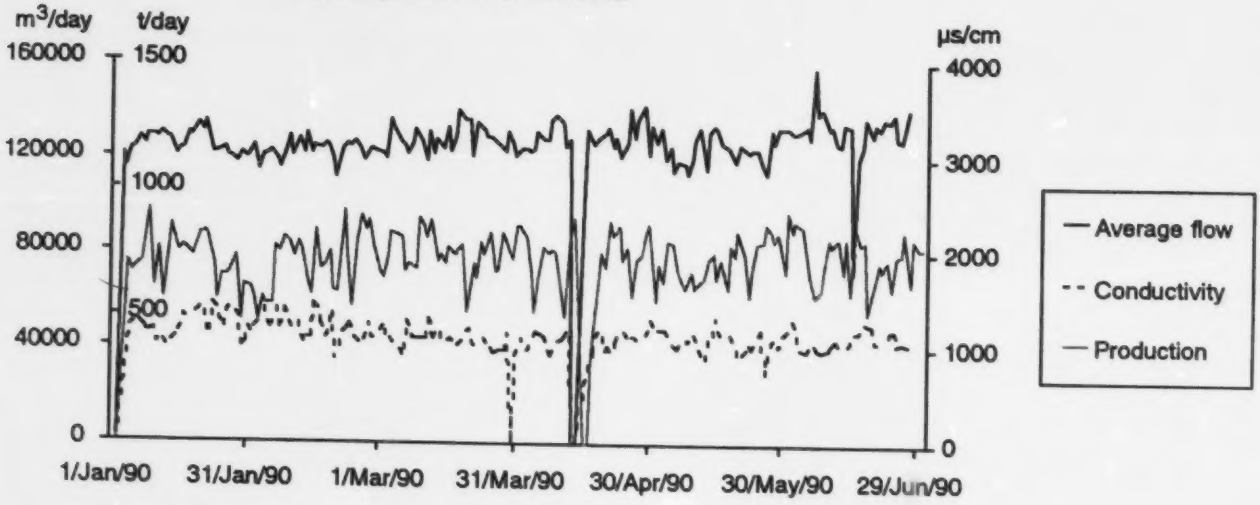
Table 8b. Metals (ATG 9 &12). Domtar Inc., Fine Papers Division (Cornwall). (Date: 18-5-1991).

Company 00001403C	Prod T/day	Daily flow m3/day	Berylium g/tonne	Aluminium g/tonne	Copper g/tonne	Zinc g/tonne	Chromium g/tonne	Nickel g/tonne	Molybdenum g/tonne	Cobalt g/tonne
Date										
Jan/90	768	128,000	-	192	-	8.1	-	-	-	-
Feb/90	838	125,000	-	180	1.5	8.2	-	-	-	-
Mar/90	742	122,000	-	236	1.6	7.8	-	-	-	-
Apr/90	502	138,000	-	412	2.7	11.3	5.5	-	-	-
May/90	679	119,000	-	211	1.8	7.0	3.5	-	-	-
Jun/90	811	134,000	-	231	-	5.7	3.3	-	-	-

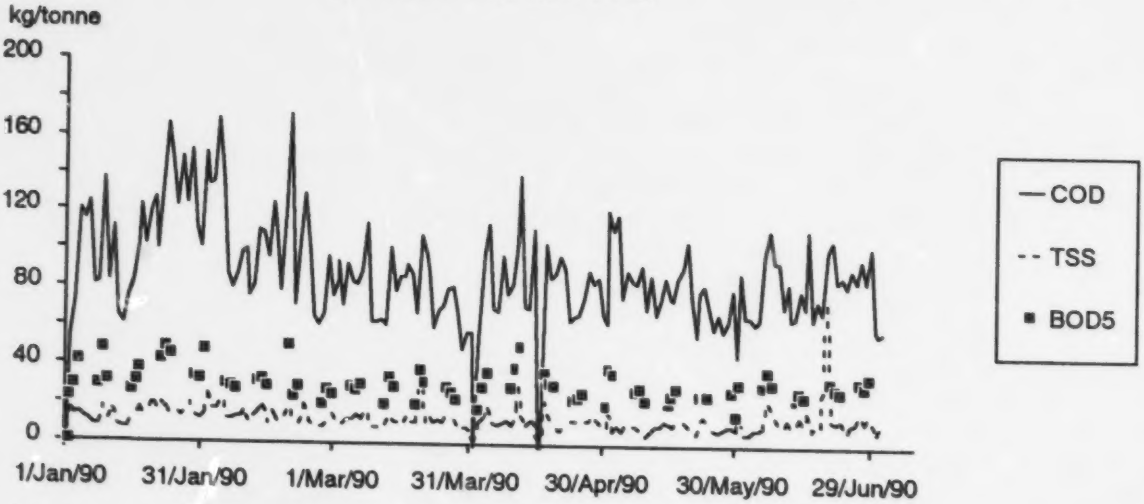
Company 00001403C	Prod T/day	Daily flow m3/day	Vanadium g/tonne	Silver g/tonne	Lead g/tonne	Cadmium g/tonne	Thallium g/tonne	Mercury g/tonne
Date								
Jan/90	768	128,000	-	-	-	-	-	0.02
Feb/90	838	125,000	2.9	-	-	0.58	-	-
Mar/90	742	122,000	-	-	-	-	-	-
Apr/90	502	138,000	5.5	-	-	-	-	-
May/90	679	119,000	-	-	-	-	-	-
Jun/90	811	134,000	-	-	-	-	-	-

Values for aluminium and zink are monthly averages

Average flow, Production and Conductivity data from Domtar Inc., Fine Papers Division (Cornwall), Control point 0100 (13-5-1991).



TSS, COD and BOD5 data from Domtar Inc., Fine Papers Division (Cornwall), Control point 0100 (13-5-1991).



Bl. Production and AOX data from Domtar Inc., Fine Papers Division (Cornwall), Control point 0100 (13-5-1991).

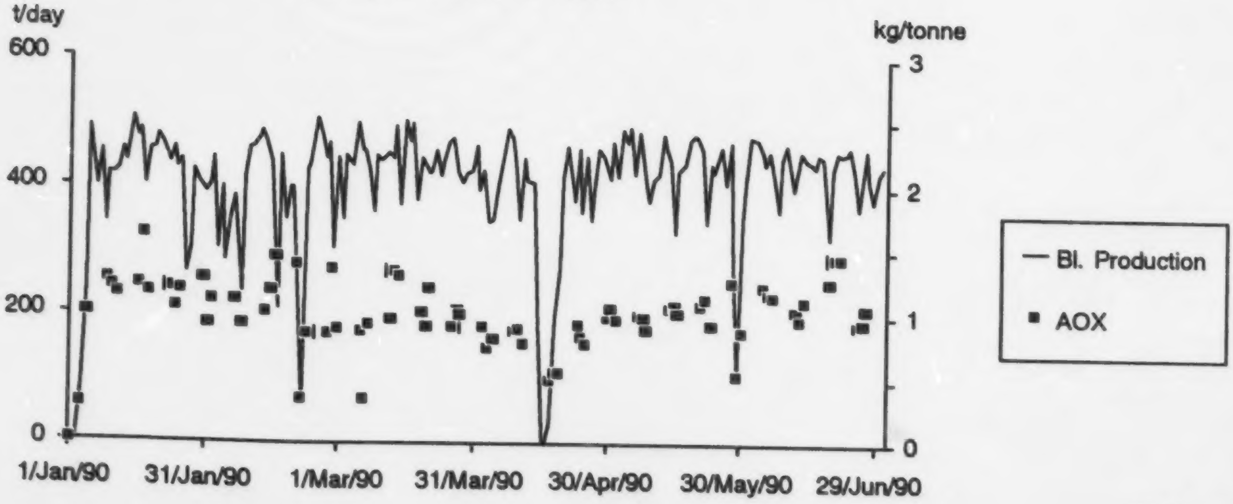


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Table 1b. Halogenated volatiles (ATG16). Domtar Inc., Containerboard Division (Red Rock). (Date: 8-5-1991).

Company: 0000140202 Cntr.pt.: 01	Bl.Prod T/day	Daily flow m3/day	Chloro-methane mg/tonne	Chloro-ethylene mg/tonne	Bromo-methane mg/tonne	Bromodi-chloromethane mg/tonne	Dichloro-methane mg/tonne	1,1-Dichloro-ethane mg/tonne	1,2-Dichloro-ethane mg/tonne	1,1-Dichloro-ethylene mg/tonne
Jan/90	54	103,710	-	-	-	-	-	-	-	-
Feb/90	57	93,900	-	-	-	-	-	-	-	-
Mar/90	62	100,280	-	-	-	-	-	-	-	-
Apr/90	57	97,735	-	-	-	-	-	-	-	-
May/90	79	97,375	-	-	-	-	-	-	-	-

Company: 0000140202 Cntr.pt.: 01	Bl.Prod T/day	Daily flow m3/day	trans-1,2-Di-chloroethylene mg/tonne	1,2-Dichloro-propane mg/tonne	cis-1,3-Di-chloropropylene mg/tonne	trans-1,3-Di-chloropropylene mg/tonne	Dibromo-ethylene mg/tonne	Trichloro-methane mg/tonne	Dibromo-chloromethane mg/tonne	Tribromo-methane mg/tonne	1,1,2-Tri-chloroethane mg/tonne
Jan/90	54	103,710	-	-	-	-	-	172,593	-	-	-
Feb/90	57	93,900	-	-	-	-	-	116,475	-	-	-
Mar/90	62	100,280	-	-	-	-	-	268,607	-	-	-
Apr/90	57	97,735	-	-	-	-	-	324,078	-	-	-
May/90	79	97,375	-	-	-	-	-	228,319	-	-	-

Company: 0000140202 Cntr.pt.: 01	Bl.Prod T/day	Daily flow m3/day	Trichloro-ethylene mg/tonne	Trifluoro-chloromethane mg/tonne	Tetrachloro-methane mg/tonne	1,1,2,2-Tetra-chloroethane mg/tonne	Tetrachloro-ethylene mg/tonne	Chloro-benzene mg/tonne	1,2-Dichloro-benzene mg/tonne	1,3-Dichloro-benzene mg/tonne	1,4-Dichloro-benzene mg/tonne
Jan/90	54	103,710	-	-	-	-	-	-	-	-	-
Feb/90	57	93,900	-	-	-	-	-	-	-	-	-
Mar/90	62	100,280	-	-	-	-	-	-	-	-	-
Apr/90	57	97,735	-	-	-	-	-	-	-	-	-
May/90	79	97,375	-	-	-	-	-	-	-	-	-

Table 2b. Nonhalogenated volatiles (ATG17). Domtar Inc., Containerboard Division (Red Rock). (Date: 8-5-1991).

Company: 0000140202

Cntr.pt.: 01	Prod T/day	Daily flow m3/day	Styrene mg/tonne	Benzene mg/tonne	m,p-Xylene mg/tonne	o-Xylene mg/tonne	Toluene mg/tonne
Date							
Jan/90	937	103,710	-	-	-	-	-
Feb/90	940	93,900	-	-	-	-	-
Mar/90	792	100,280	-	-	-	-	-
Apr/90	877	97,735	-	-	-	-	-
May/90	887	97,375	-	-	-	-	-

Table 9b. Inorganics (ATG 3, 4, 6, 7 & 15). Domtar Inc., Containerboard Division (Red Rock). (Date: 8-5-1991

Company: 0000140202

Cntr.pt.: 01	Prod. T/day	Av. flow m3/day	pH	Conductivity µs/cm	NH3 + NH4 g/tonne	NO2+NO3 g/tonne	Total-N g/tonne	Total-P g/tonne	Sulphide g/tonne
Date									
Jan/90	783	96,528	8.5	660	44	25	163	27	30
Feb/90	793	92,311	9.5	751	19	15	128	23	356
Mar/90	835	94,978	8.7	689	91	14	296	23	14
Apr/90	870	97,100	8.7	768	48	8	201	22	5
May/90	829	94,912	8.5	769	46	7	252	34	9
Jun/90	804	95,070	8.0	689	-	-	-	-	-

Table 10b. Group and unspecific variables (ATG 1, 5, 8, PP1-3). Domtar Inc., Containerboard Division (Red Rock). (Date: 8-5-1991)

Company: 0000140202

Cntr.pt.: 01	Prod. T/day	Bl.Prod T/day	Av. flow m3/tonne	BOD5 Kg/tonne	AOX Kg/tonne	COD Kg/tonne	DOC Kg/tonne	TOC Kg/tonne	TSS Kg/tonne	COD/AOX	COD/BOD
Date											
Jan/90	783	54	123.23	17.3	3.6	46.6	-	-	7.1	13	2.7
Feb/90	793	57	116.44	22.1	2.4	48.9	-	-	7.2	20	2.2
Mar/90	835	62	113.71	19.7	3.0	56.7	-	-	7.9	19	2.9
Apr/90	870	57	111.55	19.4	3.2	51.7	-	-	7.6	16	2.7
May/90	829	79	114.43	19.3	2.1	54.2	-	-	8.7	26	2.8
Jun/90	804	82	118.23	17.1	-	51.0	-	-	7.2	-	3.0

Table 3b. Extractable base neutrals (ATG19). Domtar Inc., Containerboard Division (Red Rock). (Date: 8-5-1991).

Company: 0000140202 Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	Naphthalene mg/tonne	1-Methyl-naphthalene mg/tonne	2-Methyl-naphthalene mg/tonne	1-Chloro-naphthalene mg/tonne	2-Chloro-naphthalene mg/tonne	Anthracene mg/tonne	Benz[a]-anthracene mg/tonne	Dibenz[a] anthracene mg/tonne
Date										
Jan/90	937	103,710	-	-	-	-	-	-	-	-
Feb/90	940	93,900	-	-	-	-	-	-	-	-
Mar/90	792	100,280	-	-	-	-	-	-	-	-
Apr/90	877	97,735	-	-	-	-	-	-	-	-
May/90	887	97,375	-	-	-	-	-	-	-	-

Company: 0000140202 Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	Phenan-threne mg/tonne	Acenaph-thene mg/tonne	Acenaph-thylene mg/tonne	5-Nitro-ace-naphthene mg/tonne	Chrysene mg/tonne	Fluor-anthene mg/tonne	Benz[b]-fluoranthene mg/tonne	Benz[k] fluoranthene mg/tonne	Fluorene mg/tonne
Date											
Jan/90	937	103,710	-	-	-	-	-	-	-	-	-
Feb/90	940	93,900	-	-	-	-	-	-	-	-	-
Mar/90	792	100,280	-	-	-	-	-	-	-	-	-
Apr/90	877	97,735	-	-	-	-	-	-	-	-	-
May/90	887	97,375	-	-	-	-	-	-	-	-	-

Company: 0000140202 Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	Pyrene mg/tonne	Benz[a]-pyrene mg/tonne	ıdeno[1,2,3-cd pyrene mg/tonne	Perylene mg/tonne	Benz[g,h,i]-perylene mg/tonne	Indole mg/tonne	Camphene mg/tonne
Date									
Jan/90	937	103,710	-	-	-	-	-	-	-
Feb/90	940	93,900	-	-	-	-	-	-	-
Mar/90	792	100,280	-	-	-	-	-	-	-
Apr/90	877	97,735	-	-	-	-	-	-	-
May/90	887	97,375	-	-	-	-	-	-	-

Table 4b. Acidic extractables (ATG20). Domtar Inc., Containerboard Division (Red Rock). (Date: 8-5-1991).

Company: 0000140202 Cntr.pt.: 01	Prod. T/day	Bl.Prod T/day	Daily flow m3/day	Phenol mg/tonne	m-Cresol mg/tonne	o-Cresol mg/tonne	p-Cresol mg/tonne	2,4-xylenol mg/tonne	4-Chloro-m-cresol mg/tonne	2-Chloro-phenol mg/tonne	2,4-Dichloro-phenol mg/tonne
Date											
Jan/90	937	54	103,710	-	-	-	-	-	-	-	-
Feb/90	940	57	93,900	340	-	-	-	-	-	-	-
Mar/90	792	62	100,280	671	-	-	-	-	-	-	-
Apr/90	877	57	97,735	323	-	-	-	-	-	-	-
May/90	887	79	97,375	516	-	-	-	-	-	-	-

Company: 0000140202 Cntr.pt.: 01	Prod. T/day	Bl.Prod T/day	Daily flow m3/day	2,6-Dichloro-phenol mg/tonne	2,3,4-Tri-chlorophenol mg/tonne	2,3,5-Tri-chlorophenol mg/tonne	2,4,5-Tri-chlorophenol mg/tonne	2,4,6-Tri-chlorophenol mg/tonne	2,3,4,5-Tetra-chlorophenol mg/tonne	2,3,4,6-Tetra-chlorophenol mg/tonne	2,3,5,6-Tetra-chlorophenol mg/tonne
Date											
Jan/90	937	54	103,710	-	-	-	-	6,734	-	-	-
Feb/90	940	57	93,900	-	-	-	-	6,544	-	[illegible]	-
Mar/90	792	62	100,280	-	-	-	-	7,163	-	-	-
Apr/90	877	57	97,735	-	-	-	-	6,993	-	-	-
May/90	887	79	97,375	-	-	-	-	6,788	-	-	-

Company: 0000140202 Cntr.pt.: 01	Prod. T/day	Bl.Prod T/day	Daily flow m3/day	Penta-chlorophenol mg/tonne	4-Nitro-phenol mg/tonne	2,4-Dinitro-phenol mg/tonne
Date						
Jan/90	937	54	103,710	-	-	-
Feb/90	940	57	93,900	-	-	-
Mar/90	792	62	100,280	-	-	-
Apr/90	877	57	97,735	-	-	-
May/90	887	79	97,375	-	-	-

Table 5b. Chlorinated, neutrals (ATG(23). Domtar Inc., Containerboard Division (Red Rock). (Date: 8-5-1991).

Company: 0000140202 Cntr.pt.: 01	Bl.Prod T/day	Daily flow m3/day	Hexachloro-ethane mg/tonne	Hexachloro-butadiene mg/tonne	Hexachloro-yclopentadien mg/tonne	1,2,3-Trichloro-benzene mg/tonne	1,2,4-Trichloro-benzene mg/tonne	2,4,5-Trichloro-toluene mg/tonne	1,2,3,4-Tetra-chlorobenzene mg/tonne	1,2,3,5-Tetra-chlorobenzene mg/tonne
Date										
Jan/90	54	103,710	-	-	-	-	-	-	-	-
Feb/90	57	93,900	9.8	112.9	-	-	-	-	-	-
Mar/90	62	100,280	-	-	-	-	9.8	-	-	-
Apr/90	57	97,735	-	-	-	-	-	-	-	-
May/90	79	97,375	-	-	-	-	-	-	-	-

Company: 0000140202 Cntr.pt.: 01	Bl.Prod T/day	Daily flow m3/day	1,2,4,5-Tetra-chlorobenzene mg/tonne	Penta-chlorobenzene mg/tonne	Hexa-chlorobenzene mg/tonne	Octachloro-styrene mg/tonne
Date						
Jan/90	54	103,710	-	-	-	-
Feb/90	57	93,900	-	14.7	124.3	76.9
Mar/90	62	100,280	-	-	13.0	-
Apr/90	57	97,735	-	-	-	-
May/90	79	97,375	-	-	-	-

Table 6b. Chlorinated dioxins, dibenzofuranes and PCB's (ATG(23). Domtar Inc., Containerboard Division (Red Rock). (Date: 8-5-1991).

Company: 0000140202 Cntr.pt.: 01	Bl.Prod T/day	Daily flow m3/day	2,3,7,8-TCDD µgtonne	Total TCDD µgtonne	Total TCDF µgtonne	Total PCDD µgtonne	Total PCDF µgtonne	Total HxCDD µgtonne	Total HxCDF µgtonne	Total HpCDD µgtonne
Date										
Jan/90	54	103,710	-	-	-	-	-	-	-	-
Feb/90	57	93,900	-	-	-	-	-	-	-	-
Mar/90	62	100,280	-	-	-	-	-	-	-	-
Apr/90	57	97,735	-	-	-	-	-	-	-	-
May/90	79	97,375	-	-	-	-	-	-	-	-
Jun/90	82	98,170	-	-	-	-	-	-	-	-

Company: 0000140202 Cntr.pt.: 01	Bl.Prod T/day	Daily flow m3/day	Total HpCDF µg/tonne	OCDD µg/tonne	OCDF µg/tonne	Total PCB's µg/tonne
Date						
Jan/90	54	103,710	-	731.2	-	-
Feb/90	57	93,900	-	392.6	-	-
Mar/90	62	100,280	-	-	-	-
Apr/90	57	97,735	-	545.8	-	-
May/90	79	97,375	-	419.6	-	-
Jun/90	82	98,170	-	178.9	-	-

Table 7b. Fatty and resin acids (ATG 26). Domtar Inc., Containerboard Division (Red Rock). (Date: 8-5-1991).

Company: 0000140202 Cntr.pt.: 01	Prod. T/day	Bl.Prod T/day	Daily flow m3/day	Oleic acid g/tonne	Pimaric acid g/tonne	Abietic acid g/tonne	Dehydro-abietic acid g/tonne	Isopimaric acid g/tonne	Levopimaric acid g/tonne	Neoabietic acid g/tonne
Date										
Jan/90	937	54	103,710	6.5	14.3	91.4	96.3	27.8	-	92.9
Feb/90	940	57	93,900	18.3	9.3	87.5	144.2	20.8	-	87.8
Mar/90	792	62	100,280	7.3	15.6	287.2	181.0	57.4	-	570.0
Apr/90	877	57	97,735	11.8	12.1	93.8	151.2	23.7	-	113.0
May/90	887	79	97,375	4.8	10.9	79.5	126.4	25.8	-	87.7

Company: 0000140202 Cntr.pt.: 01	Prod. T/day	Bl.Prod T/day	Daily flow m3/day	Chlorodehydro abietic acid g/tonne	ichlorodehydr abietic acid g/tonne	Total resin acids g/tonne	Total resin acids Kg/day	Total resin acids mg/l
Date								
Jan/90	937	54	103,710	-	20.2	324	304	2.93
Feb/90	940	57	93,900	-	199.6	366	344	3.66
Mar/90	792	62	100,280	151.4	30.2	1127	893	8.90
Apr/90	877	57	97,735	-	23.6	396	347	3.55
May/90	887	79	97,375	-	10.8	331	294	3.02

Values for dehydroabietic acid and dichlorodehydroabietic acid are monthly averages

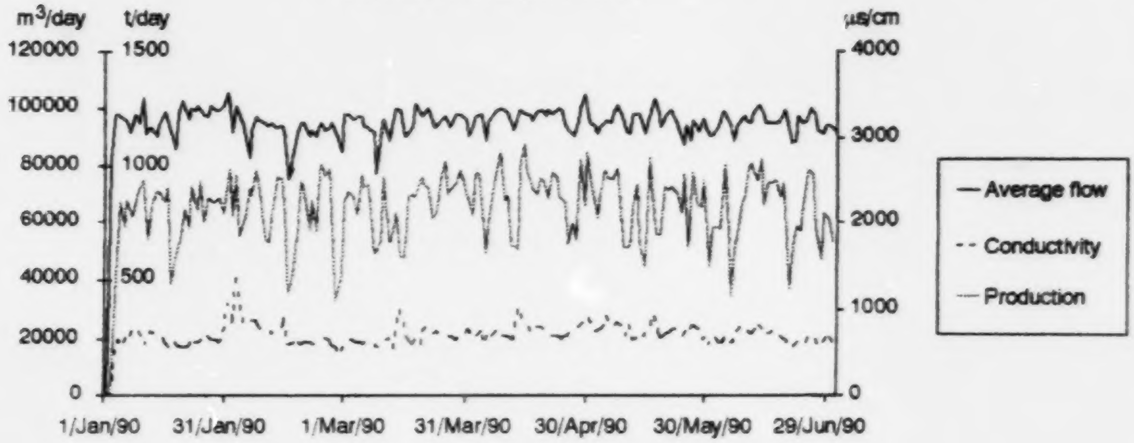
Table 8b. Metals (ATG 9 &12). Domtar Inc., Containerboard Division (Red Rock). (Date: 8-5-1991).

Company 000014020	Prod. T/day	Daily flow m3/day	g/tonne	Aluminium g/tonne	Copper g/tonne	Zinc g/tonne	Chromium g/tonne	Nickel g/tonne	Molybdenum g/tonne	Cobalt g/tonne
Date										
Jan/90	937	103,710	-	290	-	3.5	-	-	-	-
Feb/90	940	93,900	-	294	-	4.4	-	-	-	-
Mar/90	792	100,280	-	415	-	4.5	-	-	-	-
Apr/90	877	97,735	-	355	-	5.5	2.2	-	-	-
May/90	887	97,375	-	495	-	4.9	2.2	-	-	-

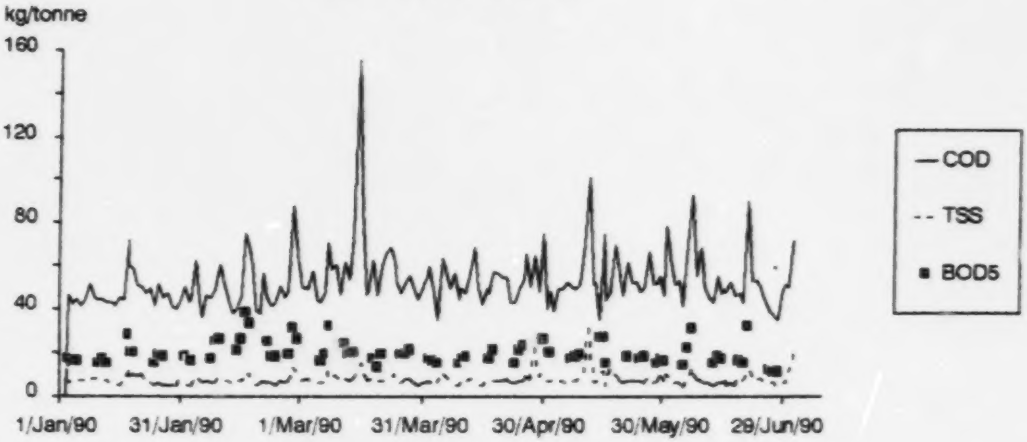
Company 000014020	Prod. T/day	Daily flow m3/day	Vanadium g/tonne	Silver g/tonne	Lead g/tonne	Cadmium g/tonne	Thallium g/tonne	Mercury g/tonne
Date								
Jan/90	937	103,710	-	-	-	-	-	-
Feb/90	940	93,900	-	-	-	-	-	-
Mar/90	792	100,280	-	-	-	-	-	-
Apr/90	877	97,735	-	-	-	-	-	-
May/90	887	97,375	-	-	-	-	-	-

Values for aluminium and zink are monthly averages.

Average flow, Production and Conductivity data from Domtar Inc., Containerboard Division (Red Rock), Control point 0100 (13-5-1991).



TSS, COD and BOD5 data from Domtar Inc., Containerboard Division (Red Rock), Control point 0100 (13-5-1991).



Bl.Production and AOX data from Domtar Inc., Containerboard Division (Red Rock), Control point 0100 (13-5-1991).

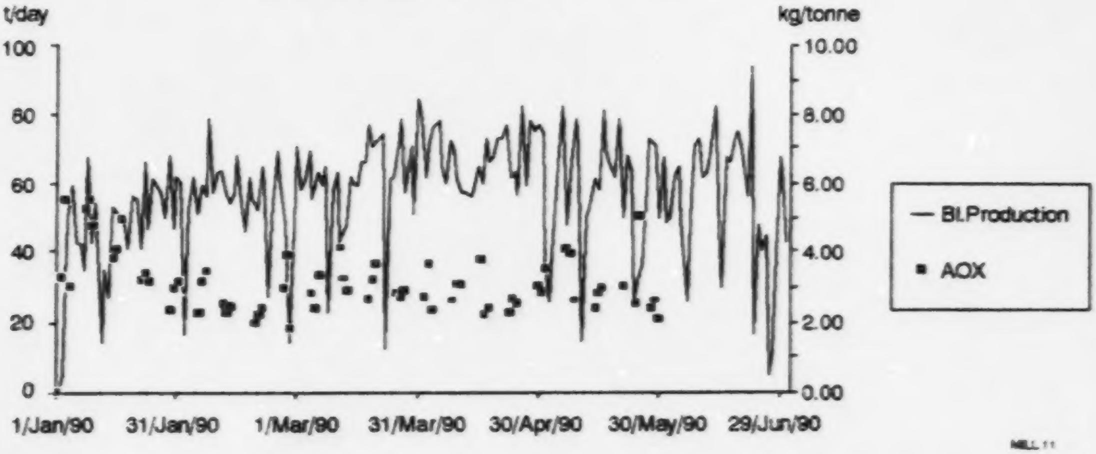


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Table 1b. Halogenated volatiles (ATG16). E.B. Eddy Forest Products Ltd. (Espanola). (Date: 3-5-1991).

Company: 0000980003

Cntr.pt.: 01	Bl.Prod T/day	Daily flow m3/day	Chloro-methane mg/tonne	Chloro-ethylene mg/tonne	Bromo-methane mg/tonne	Bromodi-chloromethane mg/tonne	Dichloro-methane mg/tonne	1,1-Dichloro-ethane mg/tonne	1,2-Dichloro-ethane mg/tonne	1,1-Dichloro-ethylene mg/tonne
Jan/90	1,067	102,035	-	-	-	-	698	-	-	-
Feb/90	1,136	100,407	610	-	442	-	-	-	-	130
Mar/90	183	32,733	2,146	-	1,520	-	-	-	-	-
Apr/90	882	109,870	-	-	287	-	1,881	-	-	-
May/90	976	120,205	-	-	-	-	246	-	-	-
Jun/90	1,156	117,518	-	-	-	-	14,232	-	-	-

Company: 0000980003

Cntr.pt.: 01	Bl.Prod T/day	Daily flow m3/day	trans-1,2-Di-chloroethylene mg/tonne	1,2-Dichloro-propane mg/tonne	cis-1,3-Di-chloropropylene mg/tonne	trans-1,3-Di-chloropropylene mg/tonne	Dibromo-ethylene mg/tonne	Trichloro-methane mg/tonne	Dibromo-chloromethane mg/tonne	Tribromo-methane mg/tonne	1,1,2-Tri-chloroethane mg/tonne
Jan/90	1,067	102,035	-	-	-	-	-	4,112	-	-	-
Feb/90	1,136	100,407	-	-	-	-	-	1,282	-	-	-
Mar/90	183	32,733	-	-	-	-	-	2,003	-	-	-
Apr/90	882	109,870	-	-	-	-	-	1,233	-	-	-
May/90	976	120,205	-	-	-	-	-	2,094	-	-	-
Jun/90	1,156	117,518	-	-	-	-	-	701	-	-	-

Company: 0000980003

Cntr.pt.: 01	Bl.Prod T/day	Daily flow m3/day	Trichloro-ethylene mg/tonne	Trifluoro-chloromethane mg/tonne	Tetrachloro-methane mg/tonne	1,1,2,2-Tetra-chloroethane mg/tonne	Tetrachloro-ethylene mg/tonne	Chloro-benzene mg/tonne	1,2-Dichloro-benzene mg/tonne	1,3-Dichloro-benzene mg/tonne	1,4-Dichloro-benzene mg/tonne
Jan/90	1,067	102,035	-	-	-	-	-	-	-	-	-
Feb/90	1,136	100,407	-	194	-	-	-	-	-	-	-
Mar/90	183	32,733	-	-	-	-	-	-	-	-	-
Apr/90	882	109,870	-	-	-	-	-	-	-	-	-
May/90	976	120,205	-	-	-	-	-	-	-	-	-
Jun/90	1,156	117,518	-	-	-	-	-	-	-	-	-

Table 2b. Nonhalogenated volatiles (ATG17). E.B. Eddy Forest Products Ltd. (Espanola). (Date: 3-5-1991).

Company: 0000980003

Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Styrene mg/tonne	Benzene mg/tonne	m,p-Xylene mg/tonne	o-Xylene mg/tonne	Toluene mg/tonne
Jan/90	1,067	102,035	-	411	-	-	78
Feb/90	1,136	100,407	33	20	-	-	102
Mar/90	183	32,733	-	-	-	-	-
Apr/90	882	109,870	-	-	-	-	-
May/90	976	120,205	-	408	-	-	79
Jun/90	1,156	117,518	-	-	-	-	40

Table 9b. Inorganics (ATG 3, 4, 6, 7 & 15). E.B. Eddy Forest Products Ltd. (Espanola). (Date: 3-5-1991).

Company: 0000980003

Cntr.pt.: 01 Date	Prod. T/day	Av. flow m3/day	pH	Conductivity µs/cm	NH3 + NH4 g/tonne	NO2+NO3 g/tonne	Total-N g/tonne	Total-P g/tonne	Sulphide g/tonne
Jan/90	1,084	104,031	6.9	1490	61	1	175	44	959
Feb/90	1,072	97,565	6.7	1424	89	10	510	68	12
Mar/90	1,067	97,115	7.6	1789	98	10	218	35	17
Apr/90	757	58,330	7.8	1632	96	10	331	50	15
May/90	1,041	114,852	7.6	1319	-	-	-	-	8
Jun/90	1,092	118,824	7.4	1371	-	-	-	-	8

Table 10b. Group and unspecific variables (ATG 1, 5, 8, PP1-3). E.B. Eddy Forest Products Ltd. (Espanola). (Date: 3-5-1991).

Company: 0000980003

Cntr.pt.: 01 Date	Prod. T/day	Bl.Prod T/day	Av. flow m3/tonne	BOD5 Kg/tonne	AOX Kg/tonne	COD Kg/tonne	DOC Kg/tonne	TOC Kg/tonne	TSS Kg/tonne	DOC/AOX	DOC/BOD
Jan/90	1,084	1,084	95.93	2.4	0.7	-	11.2	-	3.7	16.1	4.8
Feb/90	1,072	1,069	91.01	1.8	0.9	-	10.8	-	2.8	12.1	5.9
Mar/90	1,067	1,067	90.98	2.0	0.9	-	13.3	-	3.7	14.7	6.5
Apr/90	757	303	77.09	1.0	1.3	-	8.2	-	1.1	6.4	8.2
May/90	1,041	1,040	110.32	1.8	0.8	-	11.5	-	2.1	14.6	6.4
Jun/90	1,092	1,092	108.83	1.4	0.8	-	11.2	-	2.8	14.7	8.0

Table 3b. Extractable base neutrals (ATG10). E.B. Eddy Forest Products Ltd. (Espanola). (Date: 3-5-1991).

Company: 0000980003
Cntr.pt.: 01

Date	Prod T/day	Daily flow m3/day	Naphthalene mg/tonne	1-Methyl-naphthalene mg/tonne	2-Methyl-naphthalene mg/tonne	1-Chloro-naphthalene mg/tonne	2-Chloro-naphthalene mg/tonne	Anthracene mg/tonne	Benz[a]-anthracene mg/tonne	Dibenz[a] anthracene mg/tonne
Jan/90	1,067	102,035	-	-	-	-	-	-	-	-
Feb/90	1,136	100,407	-	-	-	-	-	-	-	-
Mar/90	183	32,733	-	-	-	-	-	-	-	-
Apr/90	882	109,870	-	-	-	-	-	-	-	-
May/90	976	120,205	-	-	-	-	-	-	-	-
Jun/90	1,156	117,518	-	-	-	-	-	-	-	-

Company: 0000980003
Cntr.pt.: 01

Date	Prod T/day	Daily flow m3/day	Phenanthrene mg/tonne	Acenaphthene mg/tonne	Acenaphthylene mg/tonne	5-Nitro-acenaphthene mg/tonne	Chrysene mg/tonne	Fluoranthene mg/tonne	Benz[b]-fluoranthene mg/tonne	Benz[k] fluoranthene mg/tonne	Fluorene mg/tonne
Jan/90	1,067	102,035	-	-	-	-	-	-	-	-	-
Feb/90	1,136	100,407	-	-	-	-	-	-	-	-	-
Mar/90	183	32,733	-	-	-	-	-	-	-	-	-
Apr/90	882	109,870	-	-	-	-	-	-	-	-	-
May/90	976	120,205	25	-	-	-	-	-	-	-	-
Jun/90	1,156	117,518	-	-	-	-	-	-	-	-	-

Company: 0000980003
Cntr.pt.: 01

Date	Prod T/day	Daily flow m3/day	Pyrene mg/tonne	Benz[a]-pyrene mg/tonne	Indeno[1,2,3-cd pyrene mg/tonne	Perylene mg/tonne	Benz[g,h,i]-perylene mg/tonne	Indole mg/tonne	Camphene mg/tonne
Jan/90	1,067	102,035	-	-	-	-	-	-	-
Feb/90	1,136	100,407	-	-	-	-	-	-	-
Mar/90	183	32,733	-	-	-	-	-	1109	-
Apr/90	882	109,870	-	-	-	-	-	-	-
May/90	976	120,205	-	-	-	-	-	-	-
Jun/90	1,156	117,518	-	-	-	-	-	61	-

Table 4b. Acidic extractables (ATG20). E.B. Eddy Forest Products Ltd. (Espanola). (Date: 3-5-1991).

Company: 0000980003
Cntr.pt.: 01

Date	Prod T/day	Bl Prod T/day	Daily flow m3/day	Phenol mg/tonne	m-Cresol mg/tonne	o-Cresol mg/tonne	p-Cresol mg/tonne	2,4-xylenol mg/tonne	4-Chloro-m-cresol mg/tonne	2-Chloro-phenol mg/tonne	2,4-Dichloro-phenol mg/tonne
Jan/90	1,067	1,067	102,035	-	-	-	-	-	-	-	-
Feb/90	1,136	1,136	100,407	-	-	-	-	-	-	-	-
Mar/90	183	183	32,733	-	-	-	-	-	-	-	-
Apr/90	882	882	109,870	-	-	-	-	-	-	-	212
May/90	976	976	120,205	99	406	197	209	-	-	-	-
Jun/90	1,156	1,156	117,518	71	-	-	-	-	-	-	51

Company: 0000980003
Cntr.pt.: 01

Date	Prod T/day	Bl Prod T/day	Daily flow m3/day	2,6-Dichloro-phenol mg/tonne	2,3,4-Tri-chlorophenol mg/tonne	2,3,5-Tri-chlorophenol mg/tonne	2,4,5-Tri-chlorophenol mg/tonne	2,4,6-Tri-chlorophenol mg/tonne	2,3,4,5-Tetra-chlorophenol mg/tonne	2,3,4,6-Tetra-chlorophenol mg/tonne	2,3,5,6-Tetra-chlorophenol mg/tonne
Jan/90	1,067	1,067	102,035	-	-	-	-	344	-	-	-
Feb/90	1,136	1,136	100,407	-	-	-	-	530	-	-	-
Mar/90	183	183	32,733	-	-	-	-	-	-	-	-
Apr/90	882	882	109,870	-	-	-	-	1,221	-	-	-
May/90	976	976	120,205	-	-	-	-	-	-	-	-
Jun/90	1,156	1,156	117,518	-	-	-	-	142	-	-	-

Company: 0000980003
Cntr.pt.: 01

Date	Prod T/day	Bl Prod T/day	Daily flow m3/day	Penta-chlorophenol mg/tonne	4-Nitro-phenol mg/tonne	2,4-Dinitro-phenol mg/tonne
Jan/90	1,067	1,067	102,035	-	-	-
Feb/90	1,136	1,136	100,407	-	-	-
Mar/90	183	183	32,733	-	-	-
Apr/90	882	882	109,870	-	-	-
May/90	976	976	120,205	-	-	-
Jun/90	1,156	1,156	117,518	112	-	-

Table 5b. Chlorinated, neutrals (ATG(23). E.B. Eddy Forest Products Ltd. (Espanola). (Date: 3-5-1991).

Company: 0000980003

Cntr.pt.: 01 Date	Bl.Prod T/day	Daily flow m3/day	Hexachloro-ethane mg/tonne	Hexachloro-butadiene mg/tonne	Hexachloro-yclopentadien mg/tonne	1,2,3-Trichloro-benzene mg/tonne	1,2,4-Trichloro-benzene mg/tonne	2,4,5-Trichloro-toluene mg/tonne	1,2,3,4-Tetra-chlorobenzene mg/tonne	1,2,3,5-Tetra-chlorobenzene mg/tonne
Jan/90	1,067	102,035	-	-	-	-	-	-	-	-
Feb/90	1,136	100,407	-	-	-	-	-	-	-	-
Mar/90	183	32,733	1.6	-	-	-	-	-	1.4	-
Apr/90	882	109,870	-	-	-	-	-	-	-	-
May/90	976	120,205	-	-	-	-	-	-	-	-
Jun/90	1,156	117,518	-	-	0.7	-	-	-	-	-

Company: 0000980003

Cntr.pt.: 01 Date	Bl.Prod T/day	Daily flow m3/day	1,2,4,5-Tetra-chlorobenzene mg/tonne	Penta-chlorobenzene mg/tonne	Hexa-chlorobenzene mg/tonne	Octachloro-styrene mg/tonne
Jan/90	1,067	102,035	-	-	-	-
Feb/90	1,136	100,407	-	-	-	-
Mar/90	183	32,733	-	-	-	-
Apr/90	882	109,870	-	-	-	-
May/90	976	120,205	-	-	-	-
Jun/90	1,156	117,518	-	-	-	-

Table 6b. Chlorinated dioxins, dibenzofuranes and PCB's (ATG(24). E.B. Eddy Forest Products Ltd. (Espanola). (Date: 3-5-1991).

Company: 0000980003

Cntr.pt.: 01 Date	Bl.Prod T/day	Daily flow m3/day	2,3,7,8-TCDD µgtonne	Total TCDD µgtonne	Total TCDF µgtonne	Total PCDD µgtonne	Total PCDF µgtonne	Total HxCDD µgtonne	Total HxCDF µgtonne	Total HpCDD µgtonne
Jan/90	925	95,609	-	-	6.0	-	-	-	-	-
Feb/90	956	98,538	-	-	-	-	-	-	-	-
Mar/90	1,056	88,928	-	-	-	-	-	-	-	-
Apr/90	1,051	111,865	-	-	-	-	-	-	-	-
May/90	1,125	118,592	-	-	-	-	-	-	-	-
Jun/90	1,059	117,731	-	-	10.7	-	-	-	-	-

Company: 0000980003

Cntr.pt.: 01 Date	Bl.Prod T/day	Daily flow m3/day	Total HpCDF µg/tonne	OCDD µg/tonne	OCDF µg/tonne	Total PCB's µg/tonne
Jan/90	925	95,609	-	-	-	-
Feb/90	956	98,538	-	-	-	-
Mar/90	1,056	88,928	-	-	-	-
Apr/90	1,051	111,865	-	-	-	-
May/90	1,125	118,592	-	-	-	-
Jun/90	1,059	117,731	-	-	-	-

Table 7b. Fatty and resin acids (ATG 26). E.B. Eddy Forest Products Ltd. (Espanola). (Date: 3-5-1991).

Company: 0000980003

Cntr.pt.: 01 Date	Prod. T/day	Bl.Prod T/day	Daily flow m3/day	Oleic acid g/tonne	Pimaric acid g/tonne	Abietic acid g/tonne	Dehydro-abietic acid g/tonne	Isopimaric acid g/tonne	Levopimaric acid g/tonne	Neoabietic acid g/tonne
Jan/90	1,067	1,067	102,035	-	-	-	0.9	-	-	-
Feb/90	1,136	1,136	100,407	-	-	-	1.2	-	-	-
Mar/90	183	183	32,733	-	-	-	7.6	-	-	-
Apr/90	882	882	109,870	-	-	-	0.9	-	-	-
May/90	976	976	120,205	5.5	2.1	-	0.5	3.3	-	1.4
Jun/90	1,156	1,156	117,518	-	-	-	0.3	-	-	-

Company: 0000980003

Cntr.pt.: 01 Date	Prod. T/day	Bl.Prod T/day	Daily flow m3/day	Chlorodehydro abietic acid g/tonne	ichlorodehydr abietic acid g/tonne	Total resin acids g/tonne	Total resin acids Kg/day	Total resin acids mg/l
Jan/90	1,067	1,067	102,035	-	0.4	0.9	1.0	0.01
Feb/90	1,136	1,136	100,407	-	0.4	1.2	1.4	0.01
Mar/90	183	183	32,733	-	2.1	7.6	1.4	0.04
Apr/90	882	882	109,870	-	0.3	0.9	0.8	0.01
May/90	976	976	120,205	1.2	0.5	8.5	8.3	0.07
Jun/90	1,156	1,156	117,518	-	0.4	0.3	0.4	0.00

Values for dehydroabietic acid and dichlorodehydroabietic acid are monthly averages

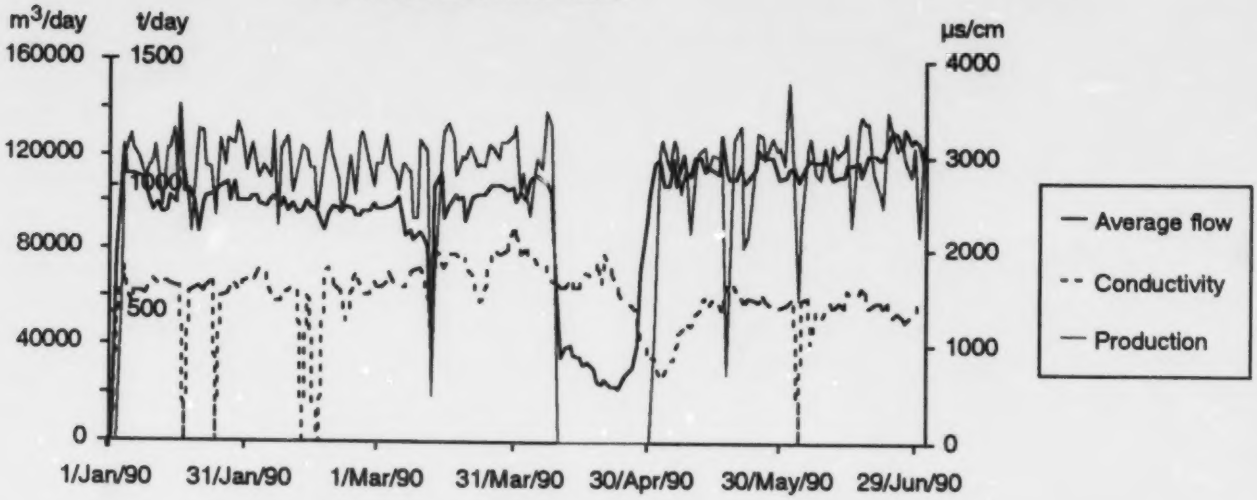
Table 8b. Metals (ATG 9 &12). E.B. Eddy Forest Products Ltd. (Espanola). (Date: 3-5-1991).

Company 00009800C	Prod. T/day	Daily flow m3/day	Berylium g/tonne	Aluminium g/tonne	Copper g/tonne	Zinc g/tonne	Chromium g/tonne	Nickel g/tonne	Molybdenum g/tonne	Cobalt g/tonne
Date										
Jan/90	1,067	102,035	-	66	1.2	9.4	-	2.9	0.5	-
Feb/90	1,136	100,407	-	60	-	11.9	4.4	5.3	-	-
Mar/90	183	32,733	-	366	5.0	55.0	3.9	6.8	-	3.9
Apr/90	882	109,870	-	116	36.1	3.7	-	2.5	-	-
May/90	976	120,205	-	130	-	4.2	-	-	-	-
Jun/90	1,156	117,518	-	58	1.3	7.7	1.4	4.2	-	1.0

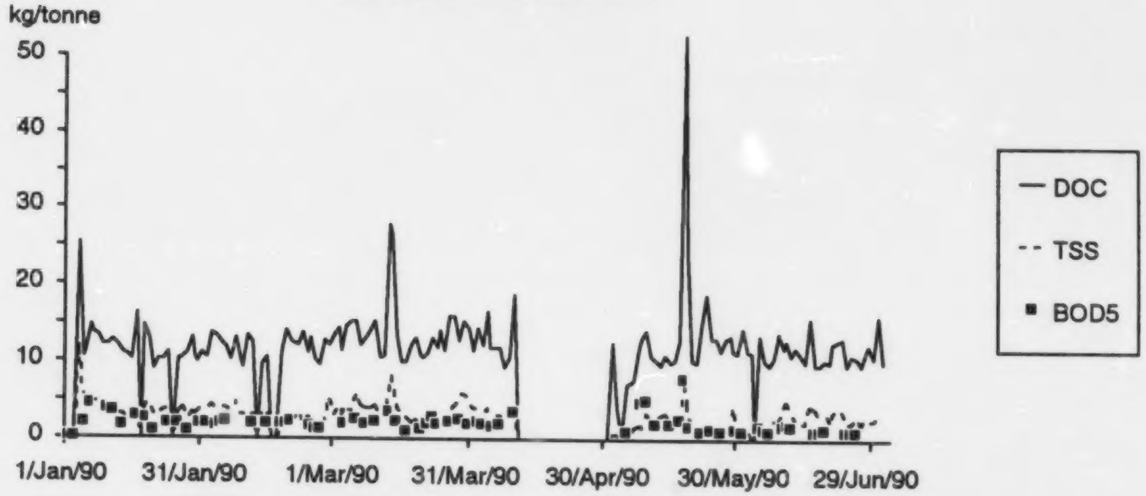
Company 00009800C	Prod. T/day	Daily flow m3/day	Vanadium g/tonne	Silver g/tonne	Lead g/tonne	Cadmium g/tonne	Thallium g/tonne	Mercury g/tonne
Date								
Jan/90	1,067	102,035	1.7	-	0.5	0.14	1.34	-
Feb/90	1,136	100,407	1.1	-	-	0.13	-	-
Mar/90	183	32,733	-	-	0.2	0.27	-	-
Apr/90	882	109,870	8.7	-	-	-	-	-
May/90	976	120,205	-	-	-	-	-	-
Jun/90	1,156	117,518	-	-	8.1	0.41	-	-

Values for aluminium and zink are monthly averages.

Average flow, Production and Conductivity data from E.B. Eddy Forest Products Ltd. (Espanola), Control point 0100 (14-5-1991).



TSS, DOC and BOD5 data from E.B. Eddy Forest Products Ltd. (Espanola), Control point 0100 (14-5-1991).



Bl. Production and AOX data from E.B. Eddy Forest Products Ltd. (Espanola), Control point 0100 (14-5-1991).

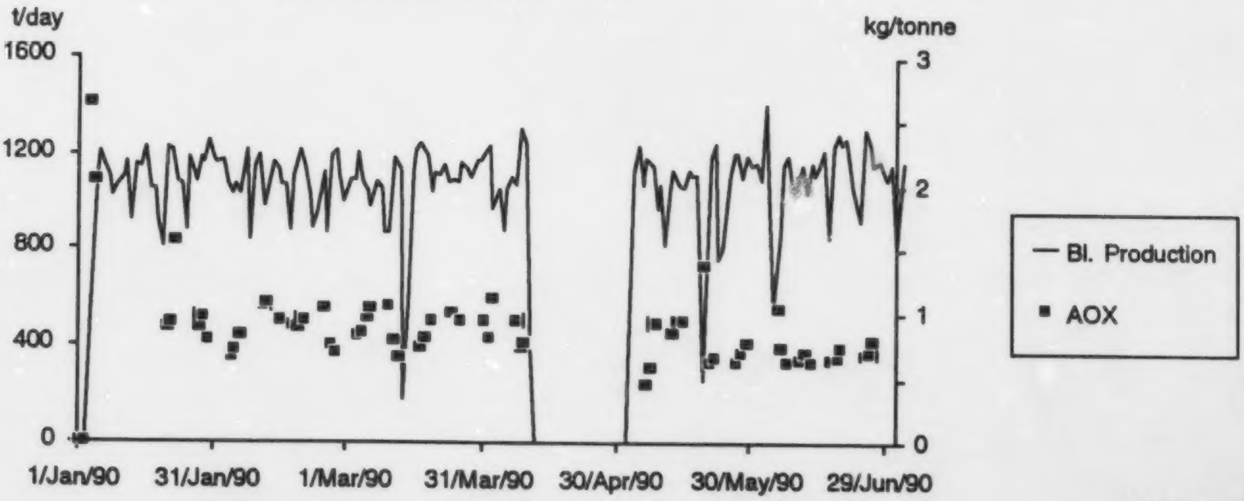


Table 1b. Halogenated volatiles (ATG16). James River-Marathon Ltd. (Marathon). (Date: 8-5-1991).

Company: 0000850008 Cntr.pt.: 01	Bl.Prod T/day	Daily flow m3/day	Chloro-methane mg/tonne	Chloro-ethylene mg/tonne	Bromo-methane mg/tonne	Bromodi-chloromethane mg/tonne	Dichloro-methane mg/tonne	1,1-Dichloro-ethane mg/tonne	1,2-Dichloro-ethane mg/tonne	1,1-Dichloro-ethylene mg/tonne
Jan/90	473	62,736	-	-	-	-	53,054	-	-	-
Feb/90	447	63,702	-	-	-	-	-	-	-	-
Mar/90	492	61,223	-	-	-	-	-	-	-	-
Apr/90	368	58,666	-	-	-	-	-	-	-	-
May/90	228	66,695	-	-	-	-	-	-	-	-
Jun/90	427	65,366	168,390	-	59,702	-	-	-	-	-

Company: 0000850008 Cntr.pt.: 01	Bl.Prod T/day	Daily flow m3/day	trans-1,2-Di-chloroethylene mg/tonne	1,2-Dichloro-propane mg/tonne	cis-1,3-Di-chloropropylen mg/tonne	trans-1,3-Di-chloropropylen mg/tonne	Dibromo-ethylene mg/tonne	Trichloro-methane mg/tonne	Dibromo-chloromethane mg/tonne	Tribromo-methane mg/tonne	1,1,2-Tri-chloroethane mg/tonne
Jan/90	473	62,736	-	-	-	-	-	225,478	-	-	-
Feb/90	447	63,702	-	-	-	-	-	91,206	-	48,453	-
Mar/90	492	61,223	-	-	-	-	-	211,543	-	-	-
Apr/90	368	58,666	-	-	-	-	-	207,244	-	-	-
May/90	228	66,695	-	-	-	-	-	193,064	-	-	-
Jun/90	427	65,366	-	-	-	-	-	116,342	-	-	-

Company: 0000850008 Cntr.pt.: 01	Bl.Prod T/day	Daily flow m3/day	Trichloro-ethylene mg/tonne	Trifluoro-chloromethane mg/tonne	Tetrachloro-methane mg/tonne	1,1,2,2-Tetra-chloroethane mg/tonne	Tetrachloro-ethylene mg/tonne	Chloro-benzene mg/tonne	1,2-Dichloro-benzene mg/tonne	1,3-Dichloro-benzene mg/tonne	1,4-Dichloro-benzene mg/tonne
Jan/90	473	62,736	-	-	-	-	-	-	-	-	-
Feb/90	447	63,702	-	-	-	-	-	-	-	-	-
Mar/90	492	61,223	-	-	-	-	-	-	-	-	-
Apr/90	368	58,666	-	-	-	-	-	-	-	-	-
May/90	228	66,695	-	-	-	-	-	-	-	-	-
Jun/90	427	65,366	-	-	-	-	29,086	-	-	-	-

Table 2b. Nonhalogenated volatiles (ATG17). James River-Marathon Ltd. (Marathon). (Date: 8-5-1991).

Company: 0000850008

Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Styrene mg/tonne	Benzene mg/tonne	m,p-Xylene mg/tonne	o-Xylene mg/tonne	Toluene mg/tonne
Jan/90	473	62,736	-	-	-	-	-
Feb/90	447	63,702	-	-	-	-	-
Mar/90	492	61,223	-	-	-	-	-
Apr/90	368	58,666	-	-	-	-	-
May/90	228	66,695	-	-	-	-	-
Jun/90	427	65,366	-	-	-	-	-

Table 9b. Inorganics (ATG 3, 4, 6, 7 & 15). James River-Marathon Ltd. (Marathon). (Date: 8-5-1991).

Company: 0000850008

Cntr.pt.: 01 Date	Prod. T/day	Av. flow m3/day	pH	Conductivity µs/cm	NH3 + NH4 g/tonne	NO2+NO3 g/tonne	Total-N g/tonne	Total-P g/tonne	Sulphide g/tonne
Jan/90	482	62,052	2.9	2782	330	4792	330	125	61
Feb/90	458	60,820	2.9	2350	466	33	473	90	56
Mar/90	435	59,667	3.1	2242	306	34	250	118	12
Apr/90	447	61,676	2.9	2077	324	35	683	211	68
May/90	272	61,327	4.4	1718	343	163	547	70	2372
Jun/90	465	65,580	3.1	1860	370	35	416	62	13

Table 10b. Group and unspecific variables (ATG 1, 5, 8, PP1-3). James River-Marathon Ltd. (Marathon). (Date: 8-5-1991).

Company: 0000850008

Cntr.pt.: 01 Date	Prod. T/day	Prod. T/day	Av. flow m3/tonne	BOD5 Kg/tonne	AOX Kg/tonne	COD Kg/tonne	DOC Kg/tonne	TOC Kg/tonne	TSS Kg/tonne	COD/AOX	COD/BOD
Jan/90	482	482	128.81	26.8	5.6	110.5	-	-	6.2	19.8	4.1
Feb/90	458	458	132.80	30.0	4.6	106.5	-	-	5.5	23.3	3.5
Mar/90	435	435	137.15	27.7	5.2	105.7	-	-	5.6	20.4	3.8
Apr/90	447	447	138.04	31.1	4.7	105.4	-	-	5.8	22.4	3.4
May/90	272	272	225.87	39.2	3.2	156.7	-	-	8.9	49.4	4.0
Jun/90	465	465	141.13	26.2	24.6	103.9	-	-	5.1	4.2	4.0

Table 3b. Extractable base neutrals (ATG19). James River-Marathon Ltd. (Marathon). (Date: 8-5-1991).

Company: 0000850008

Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Naphthalene mg/tonne	1-Methyl-naphthalene mg/tonne	2-Methyl-naphthalene mg/tonne	1-Chloro-naphthalene mg/tonne	2-Chloro-naphthalene mg/tonne	Anthracene mg/tonne	Benz[a]-anthracene mg/tonne	Dibenz[a] anthracene mg/tonne
Jan/90	473	62,736	-	-	-	-	-	-	-	-
Feb/90	447	63,702	-	-	-	-	-	-	-	-
Mar/90	492	61,223	-	-	-	-	-	-	-	-
Apr/90	368	58,666	-	-	-	-	-	-	-	-
May/90	228	66,695	-	-	-	-	-	-	-	-
Jun/90	427	65,366	-	-	-	-	-	-	-	-

Company: 0000850008

Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Phenanthrene mg/tonne	Acenaphthene mg/tonne	Acenaphthylene mg/tonne	5-Nitro-acenaphthene mg/tonne	Chrysene mg/tonne	Fluoranthene mg/tonne	Benz[b]-fluoranthene mg/tonne	Benz[k] fluoranthene mg/tonne	Fluorene mg/tonne
Jan/90	473	62,736	-	-	-	-	-	-	-	-	-
Feb/90	447	63,702	-	-	-	-	-	-	-	-	-
Mar/90	492	61,223	-	-	-	-	-	-	-	-	-
Apr/90	368	58,666	-	-	-	-	-	-	-	-	-
May/90	228	66,695	-	-	-	-	-	-	-	-	-
Jun/90	427	65,366	-	-	-	-	-	367	-	-	-

Company: 0000850008

Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Pyrene mg/tonne	Benz[a]-pyrene mg/tonne	Ideno[1,2,3-cd pyrene mg/tonne	Perylene mg/tonne	Benz[g,h,i]-perylene mg/tonne	Indole mg/tonne	Camphene mg/tonne
Jan/90	473	62,736	-	-	-	-	-	-	1086
Feb/90	447	63,702	-	-	-	-	-	-	-
Mar/90	492	61,223	-	-	-	-	-	-	672
Apr/90	368	58,666	-	-	-	-	-	-	781
May/90	228	66,695	-	-	-	-	-	-	-
Jun/90	427	65,366	-	-	-	-	-	-	-

Table 4b. Acidic extractables (ATG20). James River-Marathon Ltd. (Marathon). (Date: 8-5-1991).

Company: 0000850008

Cntr.pt.: 01 Date	Prod. T/day	Bl.Prod T/day	Daily flow m3/day	000 Phenol mg/tonne	m-Cresol mg/tonne	o-Cresol mg/tonne	p-Cresol mg/tonne	2,4-xylenol mg/tonne	4-Chloro-m-cresol mg/tonne	2-Chloro-phenol mg/tonne	2,4-Dichloro-phenol mg/tonne
Jan/90	473	473	62,736	-	-	-	-	-	-	-	-
Feb/90	447	447	63,702	-	-	-	-	-	-	-	-
Mar/90	492	492	61,223	1,232	-	-	-	-	-	-	-
Apr/90	368	368	58,666	-	-	-	-	-	-	-	-
May/90	228	228	66,695	-	-	-	-	-	-	-	-
Jun/90	427	427	65,366	260	-	-	-	-	1,408	-	-

Company: 0000850008

Cntr.pt.: 01 Date	Prod. T/day	Bl.Prod T/day	Daily flow m3/day	2,6-Dichloro-phenol mg/tonne	2,3,4-Tri-chlorophenol mg/tonne	2,3,5-Tri-chlorophenol mg/tonne	2,4,5-Tri-chlorophenol mg/tonne	2,4,6-Tri-chlorophenol mg/tonne	2,3,4,5-Tetra-chlorophenol mg/tonne	2,3,4,6-Tetra-chlorophenol mg/tonne	2,3,5,6-Tetra-chlorophenol mg/tonne
Jan/90	473	473	62,736	-	-	610	-	-	345	-	-
Feb/90	447	447	63,702	-	-	-	-	-	-	-	-
Mar/90	492	492	61,223	-	-	-	-	-	-	-	-
Apr/90	368	368	58,666	-	-	2,232	-	-	-	-	-
May/90	228	228	66,695	-	-	-	-	-	-	-	-
Jun/90	427	427	65,366	-	-	-	-	-	-	-	-

Company: 0000850008

Cntr.pt.: 01 Date	Prod. T/day	Bl.Prod T/day	Daily flow m3/day	Penta-chlorophenol mg/tonne	4-Nitro-phenol mg/tonne	2,4-Dinitro-phenol mg/tonne
Jan/90	473	473	62,736	-	-	-
Feb/90	447	447	63,702	-	-	-
Mar/90	492	492	61,223	-	-	-
Apr/90	368	368	58,666	191	-	-
May/90	228	228	66,695	-	-	-
Jun/90	427	427	65,366	-	-	-

Table 5b. Chlorinated, neutrals (ATG(23). James River-Marathon Ltd. (Marathon). (Date: 8-5-1991).

Company: 0000850008 Cntr.pt.: 01	Bl.Prod T/day	Daily flow m3/day	Hexachloro-ethane mg/tonne	Hexachloro-butadiene mg/tonne	Hexachloro-yclopentadien mg/tonne	1,2,3-Trichloro-benzene mg/tonne	1,2,4-Trichloro-benzene mg/tonne	2,4,5-Trichloro-toluene mg/tonne	1,2,3,4-Tetra-chlorobenzene mg/tonne	1,2,3,5-Tetra-chlorobenzene mg/tonne
Date										
Jan/90	473	62,736	-	4.0	6.6	4.0	-	6.6	-	0.8
Feb/90	447	63,702	-	-	-	-	-	-	-	-
Mar/90	492	61,223	-	-	-	-	-	-	-	-
Apr/90	368	58,666	-	-	-	-	-	-	-	-
May/90	228	66,695	-	-	-	-	-	-	-	-
Jun/90	427	65,366	-	1.8	-	-	-	-	-	-

Company: 0000850008 Cntr.pt.: 01	Bl.Prod T/day	Daily flow m3/day	1,2,4,5-Tetra-chlorobenzene mg/tonne	Penta-chlorobenzene mg/tonne	Hexa-chlorobenzene mg/tonne	Octachloro-styrene mg/tonne
Date						
Jan/90	473	62,736	0.8	-	8.0	-
Feb/90	447	63,702	-	-	-	-
Mar/90	492	61,223	-	-	-	-
Apr/90	368	58,666	-	-	-	-
May/90	228	66,695	-	-	-	-
Jun/90	427	65,366	-	-	-	-

Table 6b. Chlorinated dioxins, dibenzofuranes and PCB's (ATG(23). James River-Marathon Ltd. (Marathon). (Date: 8-5-1991).

Company: 0000850008 Cntr.pt.: 01	Bl.Prod T/day	Daily flow m3/day	2,3,7,8-TCDD μgtonne	Total TCDD μgtonne	Total TCDF μgtonne	Total PCDD μgtonne	Total PCDF μgtonne	Total HxCDD μgtonne	Total HxCDF μgtonne	Total HpCDD μgtonne
Date										
Jan/90	473	62,736	9.3	18.6	212.2	11.7	159.2	35.8	41.1	12.5
Feb/90	447	63,702	-	9.4	24.2	8.8	12.8	-	-	-
Mar/90	492	61,223	-	8.0	22.4	2.9	16.2	-	-	18.7
Apr/90	368	58,666	12.8	19.1	141.9	4.3	49.4	12.1	17.5	12.6
May/90	228	66,695	-	-	7.6	-	-	-	-	-
Jun/90	427	65,366	-	2.8	7.5	1.5	5.1	9.8	8.0	114.8

Company: 0000850008 Cntr.pt.: 01	Bl.Prod T/day	Daily flow m3/day	Total HpCDF μg/tonne	OCDD μg/tonne	OCDF μg/tonne	Total PCB's μg/tonne
Date						
Jan/90	473	62,736	-	55.7	-	-
Feb/90	447	63,702	-	59.9	-	-
Mar/90	492	61,223	-	94.6	-	-
Apr/90	368	58,666	27.1	54.2	23.9	-
May/90	228	66,695	-	79.0	-	-
Jun/90	427	65,366	26.0	214.3	24.5	-

Table 7b. Fatty and resin acids (ATG 26). James River-Marathon Ltd. (Marathon). (Date: 8-5-1991).

Company: 0000850008 Cntr.pt.: 01	Prod. T/day	Bl.Prod T/day	Daily flow m3/day	Oleic acid g/tonne	Pimaric acid g/tonne	Abietic acid g/tonne	Dehydro-abietic acid g/tonne	Isopimaric acid g/tonne	Levopimaric acid g/tonne	Neoabietic acid g/tonne
Date										
Jan/90	473	473	62,736	21.8	6.1	28.9	13.3	14.1	11.0	2.9
Feb/90	447	447	63,702	4.6	3.0	8.4	7.2	5.0	3.6	1.4
Mar/90	492	492	61,223	8.0	2.4	3.4	5.5	3.4	2.7	1.6
Apr/90	368	368	58,666	19.4	3.5	8.6	12.5	10.8	14.2	3.8
May/90	228	228	66,695	97.7	11.7	99.5	15.3	21.9	23.4	132.2
Jun/90	427	427	65,366	19.3	6.9	22.3	6.5	10.3	9.0	4.6

Company: 0000850008 Cntr.pt.: 01	Prod. T/day	Bl.Prod T/day	Daily flow m3/day	Chlorodehydro-abietic acid g/tonne	ichlorodehydr-abietic acid g/tonne	Total resin acids g/tonne	Total resin acids Kg/day	Total resin acids mg/l
Date								
Jan/90	473	473	62,736	13.4	22.8	85.0	40	0.64
Feb/90	447	447	63,702	88.9	7.6	114.4	51	0.80
Mar/90	492	492	61,223	30.6	6.5	47.4	23	0.38
Apr/90	368	368	58,666	19.6	7.7	68.5	25	0.43
May/90	228	228	66,695	46.2	5.1	344.8	79	1.18
Jun/90	427	427	65,366	39.8	4.1	96.8	41	0.63

Values for dehydroabietic acid and dichlorodehydroabietic acid are monthly averages

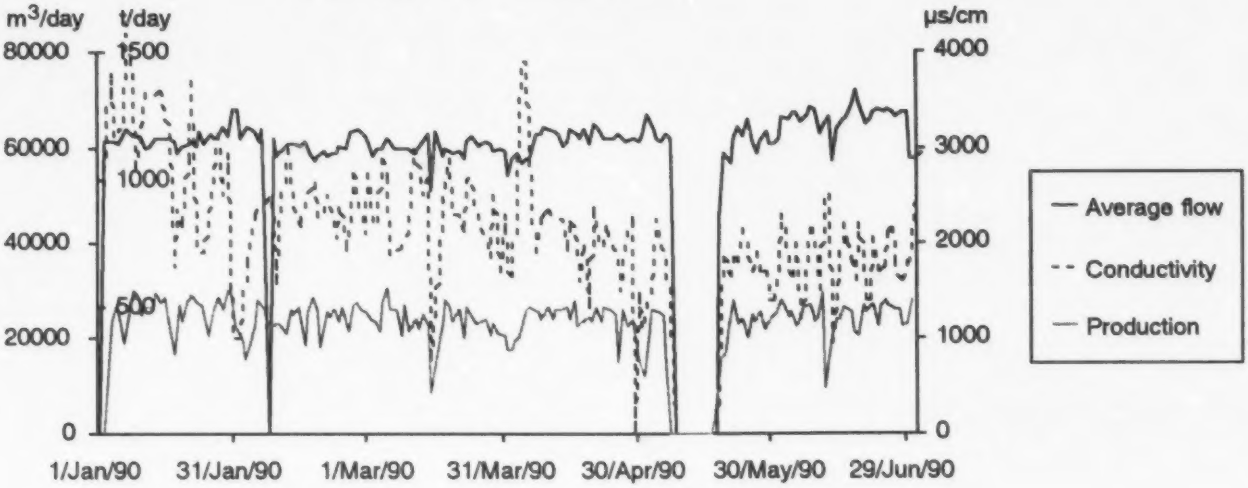
Table 6b. Metals (ATG 9 &12). James River-Marathon Ltd. (Marathon). (Date: 8-5-1991).

Company 00008500C	Prod. T/day	Daily flow m3/day	Berylium g/tonne	Aluminium g/tonne	Copper g/tonne	Zink g/tonne	Chromium g/tonne	Nickel g/tonne	Molybdenum g/tonne	Cobalt g/tonne
Date										
Jan/90	473	62,736	-	26	-	8.3	-	-	-	-
Feb/90	447	63,702	-	33	10.0	7.1	-	-	8.6	-
Mar/90	492	61,223	-	28	-	10.0	-	-	-	-
Apr/90	368	58,666	-	36	1.6	12.2	-	3.2	-	-
May/90	228	66,695	-	77	26.3	9.4	-	-	-	-
Jun/90	427	65,366	-	55	6.1	20.7	-	4.6	-	-

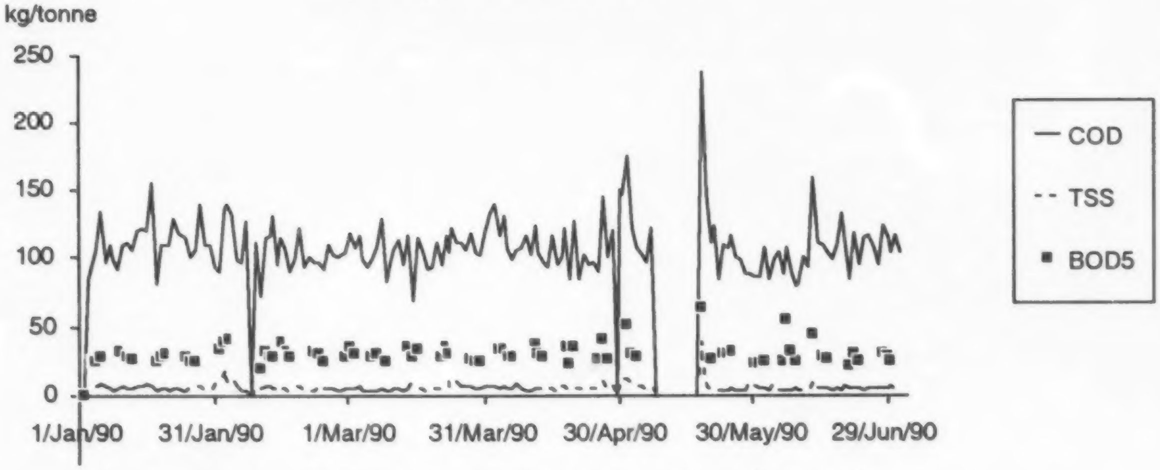
Company 00008500C	Prod. T/day	Daily flow m3/day	Vanadium g/tonne	Silver g/tonne	Lead g/tonne	Cadmium g/tonne	Thallium g/tonne	Mercury g/tonne
Date								
Jan/90	473	62,736	-	-	-	-	-	0.45
Feb/90	447	63,702	4.3	-	4.3	-	-	0.03
Mar/90	492	61,223	-	-	-	-	-	-
Apr/90	368	58,666	4.8	-	-	-	-	-
May/90	228	66,695	17.6	-	8.8	-	-	0.06
Jun/90	427	65,366	4.6	-	-	-	-	-

Values for aluminium and zink are monthly averages.

Average flow, Production and Conductivity data from James River-Marathon Ltd. (Marathon), Control point 0100 (14-5-1991).



TSS, COD and BOD5 data from James River-Marathon Ltd. (Marathon), Control point 0100 (14-5-1991).



Bl. Production and AOX data from James River-Marathon Ltd. (Marathon), Control point 0100 (14-5-1991).

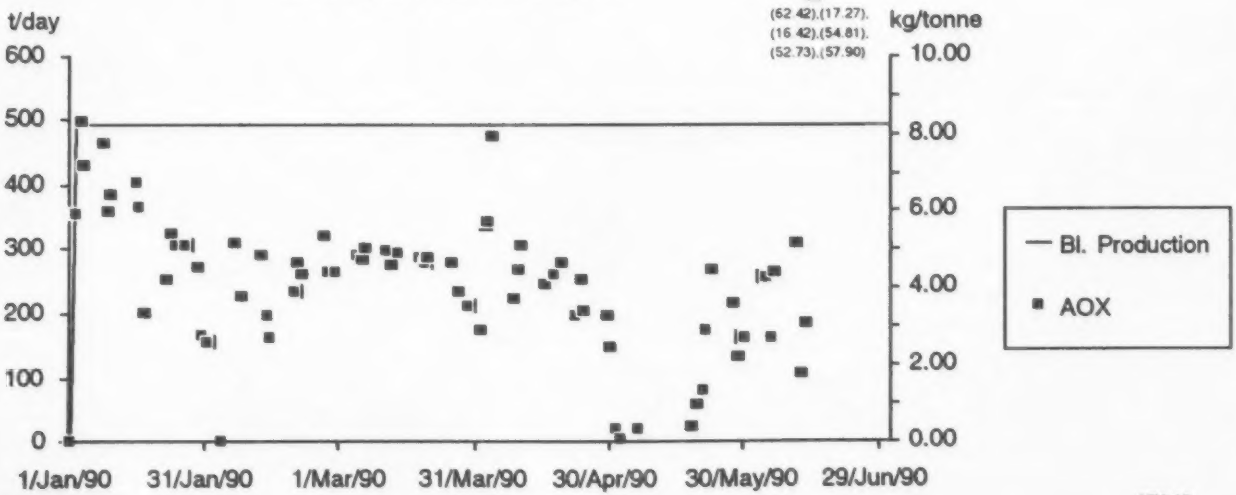


Table 1b. Halogenated volatiles (ATG16). Kimberly-Clark Canada Inc, (Terrace Bay). (Date: 8-5-1991).

Company: 0000830000

Cntr.pt.: 01	Bl.Prod T/day	Daily flow m3/day	Chloro-methane mg/tonne	Chloro-ethylene mg/tonne	Bromo-methane mg/tonne	Bromodi-chloromethane mg/tonne	Dichloro-methane mg/tonne	1,1-Dichloro-ethane mg/tonne	1,2-Dichloro-ethane mg/tonne	1,1-Dichloro-ethylene mg/tonne
Jan/90	1,228	106,283	-	-	-	-	-	-	-	-
Feb/90	1,183	104,718	-	-	-	-	-	-	-	-
Mar/90	816	106,294	-	-	-	-	-	-	-	-
Apr/90	1,102	82,454	-	-	-	-	-	-	-	-
May/90	1,182	83,876	-	-	-	-	-	-	-	-
Jun/90	1,303	88,405	-	-	-	-	-	-	-	-

Company: 0000830000

Cntr.pt.: 01	Bl.Prod T/day	Daily flow m3/day	trans-1,2-Di-chloroethylene mg/tonne	1,2-Dichloro-propane mg/tonne	cis-1,3-Di-chloropropylene mg/tonne	trans-1,3-Di-chloropropylene mg/tonne	Dibromo-ethylene mg/tonne	Trichloro-methane mg/tonne	Dibromo-chloromethane mg/tonne	Tribromo-methane mg/tonne	1,1,2-Tri-chloroethane mg/tonne
Jan/90	1,228	106,283	-	-	-	-	-	1,618	-	-	-
Feb/90	1,183	104,718	-	-	-	-	-	735	-	-	-
Mar/90	816	106,294	-	-	-	-	-	2,175	-	-	-
Apr/90	1,102	82,454	-	-	-	-	-	1,818	-	-	-
May/90	1,182	83,876	-	-	-	-	-	646	-	-	-
Jun/90	1,303	88,405	-	-	-	-	-	740	-	-	-

Company: 0000830000

Cntr.pt.: 01	Bl.Prod T/day	Daily flow m3/day	Trichloro-ethylene mg/tonne	Trifluoro-chloromethane mg/tonne	Tetrachloro-methane mg/tonne	1,1,2,2-Tetra-chloroethane mg/tonne	Tetrachloro-ethylene mg/tonne	Chloro-benzene mg/tonne	1,2-Dichloro-benzene mg/tonne	1,3-Dichloro-benzene mg/tonne	1,4-Dichloro-benzene mg/tonne
Jan/90	1,228	106,283	-	-	-	-	-	-	-	-	-
Feb/90	1,183	104,718	-	-	-	-	-	-	-	-	-
Mar/90	816	106,294	-	-	-	-	-	-	-	-	-
Apr/90	1,102	82,454	-	-	-	-	-	-	-	-	-
May/90	1,182	83,876	-	-	-	-	-	-	-	-	-
Jun/90	1,303	88,405	-	-	-	-	-	-	-	-	-

Table 2b. Nonhalogenated volatiles (ATG17). Kimberly-Clark Canada Inc, (Terrace Bay). (Date: 8-5-1991).

Company: 0000830000

Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Styrene mg/tonne	Benzene mg/tonne	m,p-Xylene mg/tonne	o-Xylene mg/tonne	Toluene mg/tonne
Jan/90	1,228	106,283	-	-	-	-	-
Feb/90	1,183	104,718	-	-	-	-	-
Mar/90	816	106,294	-	-	-	-	-
Apr/90	1,102	82,454	-	-	-	-	-
May/90	1,182	83,876	-	-	-	-	-
Jun/90	1,303	88,405	-	-	-	-	-

Table 9b. Inorganics (ATG 3, 4, 6, 7 & 15). Kimberly-Clark Canada Inc, (Terrace Bay). (Date: 8-5-1991).

Company: 0000830000

Cntr.pt.: 01 Date	Prod. T/day	Av. flow m3/day	pH	Conductivity µs/cm	NH3 + NH4 g/tonne	NO2+NO3 g/tonne	Total-N g/tonne	Total-P g/tonne	Sulphide g/tonne
Jan/90	1,141	107,065	7.5	1347	22	71	407	40	388
Feb/90	1,035	101,456	7.7	1509	38	23	404	46	1
Mar/90	1,103	100,365	7.6	1776	52	18	380	41	1
Apr/90	1,056	84,033	7.7	1975	60	16	476	46	1
May/90	1,179	86,965	7.6	2178	100	65	367	42	8
Jun/90	1,137	90,969	7.8	2219	116	11	354	44	3

Table 10b. Group and unspecific variables (ATG 1, 5, 8, PP1-3). Kimberly-Clark Canada Inc, (Terrace Bay). (Date: 8-5-1991).

Company: 0000830000

Cntr.pt.: 01 Date	Prod. T/day	Bl.Prod T/day	Av. flow m3/tonne	BOD5 Kg/tonne	AOX Kg/tonne	COD Kg/tonne	DOC Kg/tonne	TOC Kg/tonne	TSS Kg/tonne	COD/AOX	COD/BOD
Jan/90	1,141	1,141	93.83	2.8	2.2	52.5	-	-	2.9	23.9	18.9
Feb/90	1,035	1,035	98.03	1.3	2.2	83.2	-	-	4.3	29.0	47.0
Mar/90	1,103	1,103	90.98	1.1	1.9	44.0	-	-	3.5	23.3	39.7
Apr/90	1,056	1,056	79.55	1.2	1.2	40.0	-	-	4.3	32.1	34.6
May/90	1,179	1,179	73.76	0.7	1.3	44.0	-	-	3.4	33.5	58.7
Jun/90	1,137	1,137	80.04	1.0	1.9	43.1	-	-	4.2	23.1	45.4

Table 3b. Extractable base neutrals (ATG19). Kimberly-Clark Canada Inc, (Terrace Bay). (Date: 8-5-1991).

Company: 0000830000
Cntr pt.: 01

Date	Prod T/day	Daily flow m3/day	Naphthalene mg/tonne	1-Methyl-naphthalene mg/tonne	2-Methyl-naphthalena mg/tonne	1-Chloro-naphthalene mg/tonne	2-Chloro-naphthalene mg/tonne	Anthracene mg/tonne	Benz[a]-anthracene mg/tonne	Dibenz[a] anthracene mg/tonne
Jan/90	1,228	106,283	-	-	-	-	-	-	-	-
Feb/90	1,183	104,718	-	-	-	-	-	-	-	-
Mar/90	816	106,294	-	-	-	-	-	-	-	-
Apr/90	1,102	82,454	-	-	-	-	-	-	-	-
May/90	1,182	83,876	-	-	206	-	-	-	-	-
Jun/90	1,303	88,405	-	-	-	-	-	-	-	-

Company: 0000830000
Cntr pt.: 01

Date	Prod T/day	Daily flow m3/day	Phenan-threne mg/tonne	Acenaph-thene mg/tonne	Acenaph-thylene mg/tonne	5-Nitro-ace-naphthene mg/tonne	Chrysene mg/tonne	Fluor-anthene mg/tonne	Benz[b]-fluoranthene mg/tonne	Benz[k] fluoranthene mg/tonne	Fluorene mg/tonne
Jan/90	1,228	106,283	-	-	-	-	-	-	-	-	-
Feb/90	1,183	104,718	-	-	-	-	-	-	-	-	-
Mar/90	816	106,294	-	-	-	-	-	-	-	-	-
Apr/90	1,102	82,454	-	-	-	-	-	-	-	-	-
May/90	1,182	83,876	-	-	-	-	-	-	-	-	-
Jun/90	1,303	88,405	-	-	-	-	-	-	-	-	-

Company: 0000830000
Cntr pt.: 01

Date	Prod T/day	Daily flow m3/day	Pyrene mg/tonne	Benz[a]-pyrene mg/tonne	ideno[1,2,3-cd pyrene mg/tonne	Perylene mg/tonne	Benz[g,h,i]-perylene mg/tonne	indole mg/tonne	Camphene mg/tonne
Jan/90	1,228	106,283	-	-	-	-	-	-	-
Feb/90	1,183	104,718	-	-	-	-	-	-	-
Mar/90	816	106,294	-	-	-	-	-	-	-
Apr/90	1,102	82,454	-	-	-	-	-	-	-
May/90	1,182	83,876	-	-	-	-	-	-	-
Jun/90	1,303	88,405	-	-	-	-	-	-	-

Table 4b. Acidic extractables (ATG20). Kimberly-Clark Canada Inc, (Terrace Bay). (Date: 8-5-1991).

Company: 0000830000
Cntr pt.: 01

Date	Prod T/day	Bl Prod T/day	Daily flow m3/day	000 Phenol mg/tonne	m-Cresol mg/tonne	o-Cresol mg/tonne	p-Cresol mg/tonne	2,4-xylenol mg/tonne	4-Chloro-m-cresol mg/tonne	2-Chloro-phenol mg/tonne	2,4-Dichloro-phenol mg/tonne
Jan/90	1,228	1,228	106,283	-	-	-	-	-	-	-	320
Feb/90	1,183	1,183	104,718	-	-	-	-	-	-	-	292
Mar/90	816	816	106,294	-	-	-	-	-	-	-	664
Apr/90	1,102	1,102	82,454	-	-	-	-	-	-	-	202
May/90	1,182	1,182	83,876	-	-	-	-	-	-	-	206
Jun/90	1,303	1,303	88,405	-	-	-	-	-	-	-	-

Company: 0000830000
Cntr pt.: 01

Date	Prod T/day	Bl Prod T/day	Daily flow m3/day	2,6-Dichloro-phenol mg/tonne	2,3,4-Tri-chlorophenol mg/tonne	2,3,5-Tri-chlorophenol mg/tonne	2,4,5-Tri-chlorophenol mg/tonne	2,4,6-Tri-chlorophenol mg/tonne	2,3,4,5-Tetra-chlorophenol mg/tonne	2,3,4,6-Tetra-chlorophenol mg/tonne	2,3,5,6-Tetra-chlorophenol mg/tonne
Jan/90	1,228	1,228	106,283	-	-	-	-	658	-	-	-
Feb/90	1,183	1,183	104,718	-	-	-	-	531	-	-	-
Mar/90	816	816	106,294	-	-	-	-	1,146	-	-	-
Apr/90	1,102	1,102	82,454	-	-	-	-	629	-	-	-
May/90	1,182	1,182	83,876	-	-	-	-	561	128	128	-
Jun/90	1,303	1,303	88,405	-	-	-	-	122	-	-	-

Company: 0000830000
Cntr pt.: 01

Date	Prod T/day	Bl Prod T/day	Daily flow m3/day	Penta-chlorophenol mg/tonne	4-Nitro-phenol mg/tonne	2,4-Dinitro-phenol mg/tonne
Jan/90	1,228	1,228	106,283	-	-	-
Feb/90	1,183	1,183	104,718	-	-	-
Mar/90	816	816	106,294	-	-	-
Apr/90	1,102	1,102	82,454	75	-	-
May/90	1,182	1,182	83,876	-	-	-
Jun/90	1,303	1,303	88,405	-	-	-

Table 5b. Chlorinated, neutrals (ATG(23). Kimberly-Clark Canada Inc, (Terrace Bay). (Date: 8-5-1991).

Company: 0000830000

Cntr.pt.: 01 Date	Bl.Prod T/day	Daily flow m3/day	Hexachloro-ethane mg/tonne	Hexachloro-butadiene mg/tonne	Hexachloro-yclopentadien mg/tonne	1,2,3-Trichloro-benzene mg/tonne	1,2,4-Trichloro-benzene mg/tonne	2,4,5-Trichloro-toluene mg/tonne	1,2,3,4-Tetra-chlorobenzene mg/tonne	1,2,3,5-Tetra-chlorobenzene mg/tonne
Jan/90	1,228	106,283	-	-	-	-	-	-	-	-
Feb/90	1,183	104,718	-	0.4	-	-	-	-	-	-
Mar/90	816	106,294	-	-	-	-	-	-	-	-
Apr/90	1,102	82,454	-	-	-	-	-	-	-	-
May/90	1,182	83,876	-	-	-	-	-	-	-	-
Jun/90	1,303	88,405	-	-	-	-	-	-	-	-

Company: 0000830000

Cntr.pt.: 01 Date	Bl.Prod T/day	Daily flow m3/day	1,2,4,5-Tetra-chlorobenzene mg/tonne	Penta-chlorobenzene mg/tonne	Hexa-chlorobenzene mg/tonne	Octachloro-styrene mg/tonne
Jan/90	1,228	106,283	-	-	-	-
Feb/90	1,183	104,718	-	-	-	-
Mar/90	816	106,294	-	-	-	-
Apr/90	1,102	82,454	-	-	-	-
May/90	1,182	83,876	-	-	-	-
Jun/90	1,303	88,405	-	-	-	-

Table 6b. Chlorinated dioxins, dibenzofuranes and PCB's (ATG(24). Kimberly-Clark Canada Inc, (Terrace Bay). (Date: 8-5-1991).

Company: 0000830000

Cntr.pt.: 01 Date	Bl.Prod T/day	Daily flow m3/day	2,3,7,8-TCDD µgtonne	Total TCDD µgtonne	Total TCDF µgtonne	Total PCDD µgtonne	Total PCDF µgtonne	Total HxCDD µgtonne	Total HxCDF µgtonne	Total HpCDD µgtonne
Jan/90	1,228	106,283	-	13.8	18.2	-	-	-	-	-
Feb/90	1,183	104,718	-	4.8	18.6	-	-	-	-	1.8
Mar/90	917	80,121	-	-	26.2	-	4.4	-	-	4.4
Apr/90	1,102	82,454	-	-	30.7	-	4.2	-	-	-
May/90	1,182	83,876	-	3.3	27.7	-	3.8	-	-	1.8
Jun/90	1,185	93,943	-	62.6	52.3	-	6.7	-	3.1	2.0

Company: 0000830000

Cntr.pt.: 01 Date	Bl.Prod T/day	Daily flow m3/day	Total HpCDF µg/tonne	OCDD µg/tonne	OCDF µg/tonne	Total PCB's µg/tonne
Jan/90	1,228	106,283	-	24.2	-	-
Feb/90	1,183	104,718	-	168.2	-	-
Mar/90	917	80,121	-	33.2	-	-
Apr/90	1,102	82,454	-	10.5	-	-
May/90	1,182	83,876	-	-	-	-
Jun/90	1,185	93,943	-	19.8	-	-

Table 7b. Fatty and resin acids (ATG 26). Kimberly-Clark Canada Inc, (Terrace Bay). (Date: 8-5-1991).

Company: 0000830000

Cntr.pt.: 01 Date	Prod. T/day	Bl.Prod T/day	Daily flow m3/day	Oleic acid g/tonne	Pimaric acid g/tonne	Abietic acid g/tonne	Dehydro-abietic acid g/tonne	Isopimaric acid g/tonne	Levopimaric acid g/tonne	Neoabietic acid g/tonne
Jan/90	1,228	1,228	106,283	1.0	0.4	9.3	1.5	-	-	-
Feb/90	1,183	1,183	104,718	-	-	-	0.6	-	-	-
Mar/90	816	816	106,294	-	-	-	1.0	-	-	-
Apr/90	1,102	1,102	82,454	-	-	0.6	0.9	-	-	-
May/90	1,182	1,182	83,876	-	-	-	0.4	-	-	-
Jun/90	1,303	1,303	88,405	-	-	-	0.4	-	-	-

Company: 0000830000

Cntr.pt.: 01 Date	Prod. T/day	Bl.Prod T/day	Daily flow m3/day	Chlorodehydro-abietic acid g/tonne	ichlorodehydr-abietic acid g/tonne	Total resin acids g/tonne	Total resin acids Kg/day	Total resin acids mg/l
Jan/90	1,228	1,228	106,283	1.1	0.9	12.3	15	0.14
Feb/90	1,183	1,183	104,718	-	1.8	0.6	1	0.01
Mar/90	816	816	106,294	-	1.1	1.0	1	0.01
Apr/90	1,102	1,102	82,454	-	0.5	1.5	2	0.02
May/90	1,182	1,182	83,876	-	0.4	0.4	0	0.01
Jun/90	1,303	1,303	88,405	-	0.4	0.4	1	0.01

Values for dehydroabietic acid and dichlorodehydroabietic acid are monthly averages

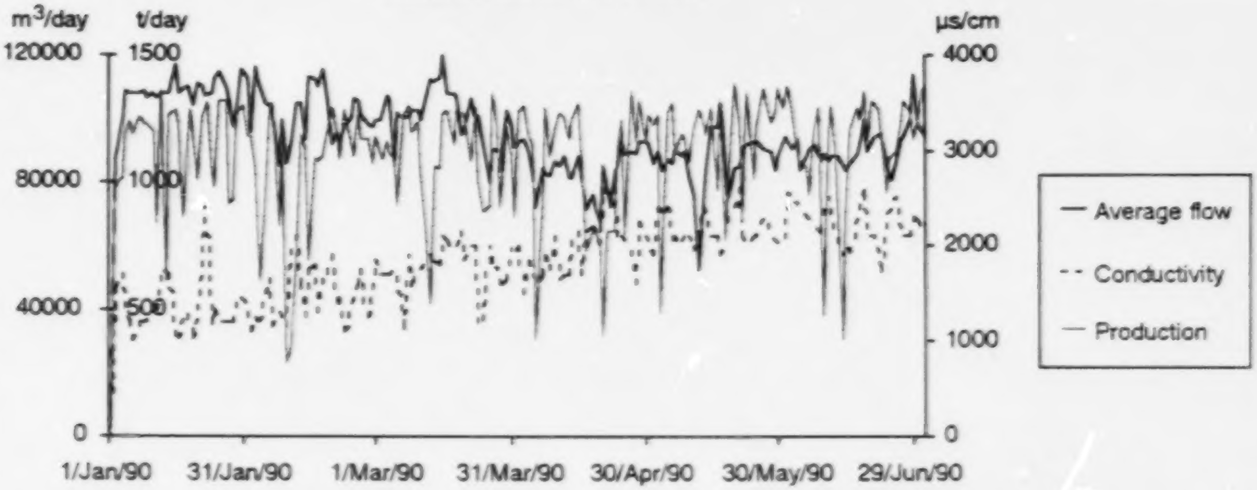
Table 8b. Metals (ATG 9 &12). Kimberly-Clark Canada Inc, (Terrace Bay). (Date: 8-5-1991).

Company 00008300C	Prod T/day	Daily flow m3/day	Berylium g/tonne	Aluminium g/tonne	Copper g/tonne	Zinc g/tonne	Chromium g/tonne	Nickel g/tonne	Molybdenum g/tonne	Cobalt g/tonne
Date										
Jan/90	1,228	106,283	-	33	-	7.8	6.9	0.9	-	-
Feb/90	1,183	104,718	-	29	-	8.1	16.8	1.8	-	-
Mar/90	816	106,294	-	52	-	11.1	18.2	2.6	-	-
Apr/90	1,102	82,454	-	35	0.7	6.7	11.2	0.7	-	-
May/90	1,182	83,876	-	44	-	5.2	8.5	0.7	-	-
Jun/90	1,303	88,405	-	44	-	6.1	20.4	0.7	-	-

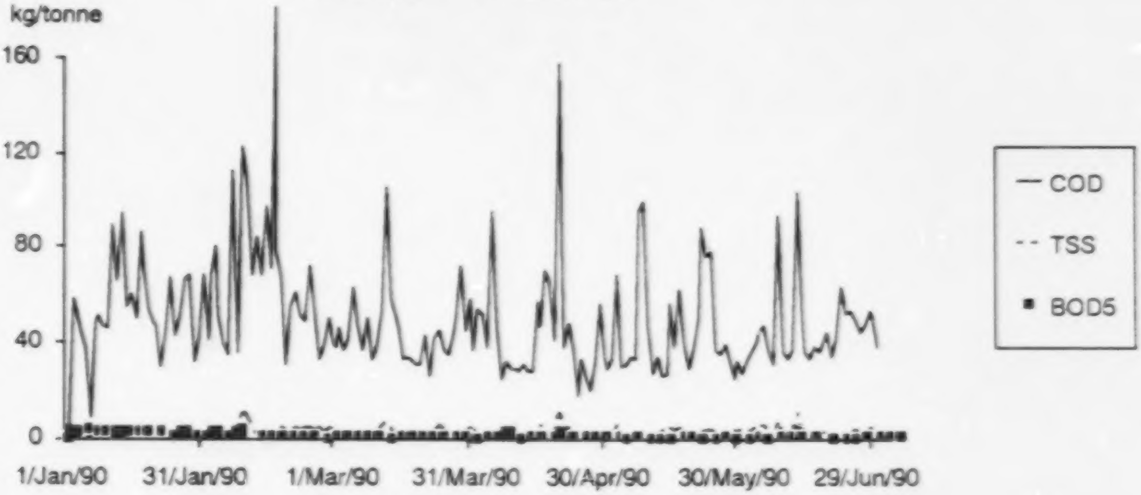
Company 00008300C	Prod T/day	Daily flow m3/day	Vanadium g/tonne	Silver g/tonne	Lead g/tonne	Cadmium g/tonne	Thallium g/tonne	Mercury g/tonne
Date								
Jan/90	1,228	106,283	-	-	-	-	-	0.01
Feb/90	1,183	104,718	-	-	2.7	0.27	-	-
Mar/90	816	106,294	-	-	-	-	-	0.01
Apr/90	1,102	82,454	-	-	-	-	-	-
May/90	1,182	83,876	1.4	-	-	-	-	-
Jun/90	1,303	88,405	-	-	-	-	-	-

Values for aluminium and zink are monthly averages

Average flow, Production and Conductivity data from Kimberly-Clark Canada Inc, (Terrace Bay), Control point 0100 (15-5-1991).



TSS, COD and BOD5 data from Kimberly-Clark Canada Inc, (Terrace Bay), Control point 0100 (15-5-1991).



Bl. Production and AOX data from Kimberly-Clark Canada Inc, (Terrace Bay), Control point 0100 (15-5-1991).

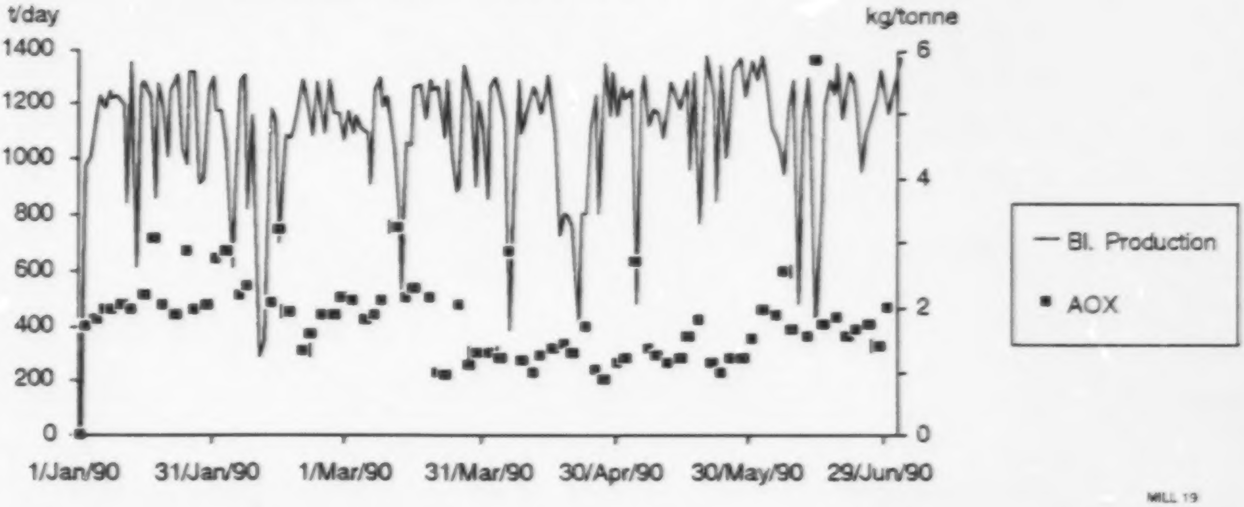


Table 1b. Halogenated volatiles (ATG16). Malette Kraft Pulp and Power Co. (Smooth Rock Falls). (Date: 3-5-1991).

Company 0000860502

Cntr pt: 04	Bl.Prod T/day	Daily flow m3/day	Chloromethane mg/tonne	Chloroethylene mg/tonne	Bromomethane mg/tonne	Bromodichloromethane mg/tonne	Dichloromethane mg/tonne	1,1-Dichloroethane mg/tonne	1,2-Dichloroethane mg/tonne	1,1-Dichloroethylene mg/tonne
Jan/90	340	46,730	-	-	-	-	-	-	-	-
Feb/90	335	48,960	2,309	-	12,277	-	585	-	-	-
Mar/90	300	50,060	-	-	-	-	1,635	-	-	-
Apr/90	362	54,670	1,329	-	-	-	-	-	-	-
May/90	319	46,650	-	-	-	-	-	-	-	-
Jun/90	353	53,930	-	-	-	-	3,514	-	-	-

Company 0000860502

Cntr pt: 04	Bl.Prod T/day	Daily flow m3/day	trans-1,2-Dichloroethylene mg/tonne	1,2-Dichloropropane mg/tonne	cis-1,3-Dichloropropylene mg/tonne	trans-1,3-Dichloropropylene mg/tonne	Dibromoethylene mg/tonne	Trichloromethane mg/tonne	Dibromochloromethane mg/tonne	Tribromomethane mg/tonne	1,1,2-Trichloroethane mg/tonne
Jan/90	340	46,730	-	-	-	-	-	13,607	-	-	-
Feb/90	335	48,960	-	-	-	-	-	14,176	-	-	-
Mar/90	300	50,060	-	-	-	-	-	2,253	-	-	-
Apr/90	362	54,670	-	-	-	-	-	22,049	-	-	-
May/90	319	46,650	-	-	-	-	-	-	-	-	-
Jun/90	353	53,930	-	-	-	-	-	19,250	-	-	-

Company 0000860502

Cntr pt: 04	Bl.Prod T/day	Daily flow m3/day	Trichloroethylene mg/tonne	Trifluorochloromethane mg/tonne	Tetrachloromethane mg/tonne	1,1,2,2-Tetrachloroethane mg/tonne	Tetrachloroethylene mg/tonne	Chlorobenzene mg/tonne	1,2-Dichlorobenzene mg/tonne	1,3-Dichlorobenzene mg/tonne	1,4-Dichlorobenzene mg/tonne
Jan/90	340	46,730	-	-	-	-	-	-	-	-	-
Feb/90	335	48,960	-	-	-	-	-	-	-	-	-
Mar/90	300	50,060	-	-	-	-	-	-	-	-	-
Apr/90	362	54,670	-	-	-	-	-	-	-	-	-
May/90	319	46,650	-	-	-	-	-	-	-	-	-
Jun/90	353	53,930	-	-	-	-	-	-	-	-	67

Table 2b. Nonhalogenated volatiles (ATG17). Malette Kraft Pulp and Power Co. (Smooth Rock Falls). (Date: 3-5-1991).

Company 0000860502

Cntr pt: 04 Date	Prod T/day	Daily flow m3/day	Styrene mg/tonne	Benzene mg/tonne	m,p-Xylene mg/tonne	o-Xylene mg/tonne	Toluene mg/tonne
Jan/90	340	46,730	236	48	36	-	412
Feb/90	335	48,960	351	-	38	-	745
Mar/90	300	50,060	230	-	-	90	551
Apr/90	362	54,670	248	82	-	-	423
May/90	319	46,650	-	-	-	-	-
Jun/90	353	53,930	-	-	-	-	37

Table 9b. Inorganics (ATG 3, 4, 6, 7 & 15). Malette Kraft Pulp and Power Co. (Smooth Rock Falls). (Date: 3-5-1991).

Company 0000860502

Cntr pt: 04 Date	Prod T/day	Av. flow m3/day	pH	Conductivity µs/cm	NH3 + NH4 g/tonne	NO2+NO3 g/tonne	Total-N g/tonne	Total-P g/tonne	Sulphide g/tonne
Jan/90	279	47,922	6.3	1512	198	17	481	52	1717
Feb/90	305	49,309	4.8	1510	161	20	323	64	11
Mar/90	288	50,016	4.7	1718	136	39	316	68	89
Apr/90	296	50,041	3.9	1490	157	42	339	63	17
May/90	304	49,267	4.0	1651	151	83	385	54	11
Jun/90	304	50,592	3.1	1676	77	202	298	62	4

Table 10b. Group and unspecific variables (ATG 1, 5, 8, PP1-3). Malette Kraft Pulp and Power Co. (Smooth Rock Falls). (Date: 3-5-1991)

Company 0000860502

Cntr.pt.: 04 Date	Prod T/day	Prod T/day	Av. flow m3/tonne	BOD5 Kg/tonne	AOX Kg/tonne	COD Kg/tonne	DOC Kg/tonne	TOC Kg/tonne	TSS Kg/tonne	COD/AOX	COD/BOD
Jan/90	279	279	171.74	38.4	3.2	208.5	-	-	5.2	65.5	5.4
Feb/90	305	305	161.67	24.0	3.7	167.1	-	-	4.0	45.2	7.0
Mar/90	288	288	173.69	29.3	5.1	82.5	-	-	5.0	16.1	2.8
Apr/90	296	296	169.24	25.5	4.5	39.3	-	-	5.3	8.6	1.5
May/90	304	304	162.04	25.0	4.0	26.0	-	-	5.2	6.4	1.0
Jun/90	304	304	166.51	25.5	5.0	70.4	-	-	5.0	14.0	2.8

Table 3b. Extractable base neutrals (ATG10). Malette Kraft Pulp and Power Co. (Smooth Rock Falls). (Date: 3-5-1991).

Company: 0000860502

Cntr.pt.: 04 Date	Prod T/day	Daily flow m3/day	Naphthalene mg/tonne	1-Methyl-naphthalene mg/tonne	2-Methyl-naphthalene mg/tonne	1-Chloro-naphthalene mg/tonne	2-Chloro-naphthalene mg/tonne	Anthracene mg/tonne	Benz[a]-anthracene mg/tonne	Dibenz[a] anthracene mg/tonne
Jan/90	340	46,730	-	-	-	-	-	-	-	-
Feb/90	335	48,960	-	-	-	-	-	-	-	-
Mar/90	300	50,060	-	-	-	-	-	-	-	-
Apr/90	362	54,670	-	-	-	-	-	-	-	-
May/90	319	46,650	29	-	-	-	-	-	-	-
Jun/90	353	53,930	46	-	-	-	-	-	-	-

Company: 0000860502

Cntr.pt.: 04 Date	Prod T/day	Daily flow m3/day	Phenan-threne mg/tonne	Acenaph-thene mg/tonne	Acenaph-thylene mg/tonne	5-Nitro-ace-naphthene mg/tonne	Chrysene mg/tonne	Fluor-anthene mg/tonne	Benz[b]-fluoranthene mg/tonne	Benz[k] fluoranthene mg/tonne	Fluorene mg/tonne
Jan/90	340	46,730	-	-	-	-	-	-	-	-	-
Feb/90	335	48,960	-	-	-	-	-	-	-	-	-
Mar/90	300	50,060	-	-	-	-	-	-	-	-	-
Apr/90	362	54,670	-	-	-	-	-	-	-	-	-
May/90	319	46,650	-	-	-	-	-	-	-	-	-
Jun/90	353	53,930	-	-	-	-	-	-	-	-	-

Company: 0000860502

Cntr.pt.: 04 Date	Prod. T/day	Daily flow m3/day	Pyrene mg/tonne	Benz[a]-pyrena mg/tonne	ideno[1,2,3-cd pyrene mg/tonne	Perylene mg/tonne	Benz[g,h,i]-perylene mg/tonne	Indole mg/tonne	Camphene mg/tonne
Jan/90	340	46,730	-	-	-	-	-	-	3573
Feb/90	335	48,960	-	-	-	-	-	-	4969
Mar/90	300	50,060	-	-	-	-	-	-	3504
Apr/90	362	54,670	108	-	-	-	-	-	-
May/90	319	46,650	-	-	-	-	-	-	731
Jun/90	353	53,930	-	-	-	-	-	-	137

Table 4b. Acidic extractables (ATG20). Malette Kraft Pulp and Power Co. (Smooth Rock Falls). (Date: 3-5-1991).

Company: 0000860502

Cntr.pt.: 04 Date	Prod T/day	Bl.Prod T/day	Daily flow m3/day	Phenol mg/tonne	m-Cresol mg/tonne	o-Cresol mg/tonne	p-Cresol mg/tonne	2,4-xylenol mg/tonne	4-Chloro-m-cresol mg/tonne	2-Chloro-phenol mg/tonne	2,4-Dichloro-phenol mg/tonne
Jan/90	340	340	46,730	2,735	2,721	-	797	-	-	-	412
Feb/90	335	335	48,960	5,846	4,677	745	687	-	-	-	892
Mar/90	300	300	50,060	6,007	4,839	684	734	-	-	-	-
Apr/90	362	362	54,670	3,322	4,531	634	529	272	76	-	634
May/90	319	319	46,650	3,217	3,802	351	366	234	-	-	775
Jun/90	353	353	53,930	2,918	1,726	137	229	122	31	336	-

Company: 0000860502

Cntr.pt.: 04 Date	Prod. T/day	Bl.Prod T/day	Daily flow m3/day	2,6-Dichloro-phenol mg/tonne	2,3,4-Tri-chlorophenol mg/tonne	2,3,5-Tri-chlorophenol mg/tonne	2,4,5-Tri-chlorophenol mg/tonne	2,4,6-Tri-chlorophenol mg/tonne	2,3,4,5-Tetra-chlorophenol mg/tonne	2,3,4,6-Tetra-chlorophenol mg/tonne	2,3,5,6-Tetra-chlorophenol mg/tonne
Jan/90	340	340	46,730	-	-	-	-	632	-	-	-
Feb/90	335	335	48,960	-	-	-	-	1,564	-	-	-
Mar/90	300	300	50,060	-	-	-	-	-	-	-	-
Apr/90	362	362	54,670	-	-	-	-	1,691	-	-	936
May/90	319	319	46,650	-	-	-	-	-	-	-	409
Jun/90	353	353	53,930	-	-	-	-	1,008	-	-	-

Company: 0000860502

Cntr.pt.: 04 Date	Prod. T/day	Bl.Prod T/day	Daily flow m3/day	Penta-chlorophenol mg/tonne	4-Nitro-phenol mg/tonne	2,4-Dinitro-phenol mg/tonne
Jan/90	340	340	46,730	-	-	-
Feb/90	335	335	48,960	-	-	-
Mar/90	300	300	50,060	-	-	-
Apr/90	362	362	54,670	408	-	-
May/90	319	319	46,650	-	-	-
Jun/90	353	353	53,930	-	-	-

Table 5b. Chlorinated, neutrals (ATG(23). Malette Kraft Pulp and Power Co. (Smooth Rock Falls). (Date: 3-5-1991).

Company: 0000860502 Cntr.pt.: 04	Bl.Prod T/day	Daily flow m3/day	Hexachloro-ethane mg/tonne	Hexachloro-butadiene mg/tonne	Hexachloro-cyclopentadien mg/tonne	1,2,3-Trichloro-benzene mg/tonne	1,2,4-Trichloro-benzene mg/tonne	2,4,5-Trichloro-toluene mg/tonne	1,2,3,4-Tetra-chlorobenzene mg/tonne	1,2,3,5-Tetra-chlorobenzene mg/tonne
Date										
Jan/90	340	46,730	-	-	-	-	-	0.0	-	-
Feb/90	335	48,960	0.7	-	4.7	-	2.5	1.6	-	-
Mar/90	300	50,060	-	-	2.7	-	-	3.0	-	-
Apr/90	362	54,670	-	-	-	-	1.2	-	-	-
May/90	319	46,650	-	-	1.6	-	-	0.3	-	-
Jun/90	353	53,930	-	-	-	-	6.0	2.4	-	-

Company: 0000860502 Cntr.pt.: 04	Bl.Prod T/day	Daily flow m3/day	1,2,4,5-Tetra-chlorobenzene mg/tonne	Penta-chlorobenzene mg/tonne	Hexa-chlorobenzene mg/tonne	Octachloro-styrene mg/tonne
Date						
Jan/90	340	46,730	-	-	-	-
Feb/90	335	48,960	-	-	-	-
Mar/90	300	50,060	-	-	-	-
Apr/90	362	54,670	-	-	-	-
May/90	319	46,650	-	-	1.0	-
Jun/90	353	53,930	-	-	-	-

Table 6b. Chlorinated dioxins, dibenzofuranes and PCB's (ATG(23). Malette Kraft Pulp and Power Co. (Smooth Rock Falls)

Company: 0000860502 Cntr.pt.: 04	Bl.Prod T/day	Daily flow m3/day	2,3,7,8-TCDD µg/tonne	Total TCDD µg/tonne	Total TCDF µg/tonne	Total PCDD µg/tonne	Total PCDF µg/tonne	Total HxCDD µg/tonne	Total HxCDF µg/tonne	Total HpCDD µg/tonne
Date										
Jan/90	340	46,730	-	-	13.7	-	-	-	-	-
Feb/90	335	48,960	-	-	-	-	-	-	-	-
Mar/90	300	50,060	-	-	3.0	-	-	-	-	-
Apr/90	362	54,670	-	-	-	-	-	-	-	-
May/90	319	46,650	-	-	33.6	-	-	-	-	-
Jun/90	353	53,930	-	-	82.5	-	-	-	-	-

Company: 0000860502 Cntr.pt.: 04	Bl.Prod T/day	Daily flow m3/day	Total HpCDF µg/tonne	OCDD µg/tonne	OCDF µg/tonne	Total PCB's µg/tonne
Date						
Jan/90	340	46,730	-	2.7	-	-
Feb/90	335	48,960	-	-	-	-
Mar/90	300	50,060	-	-	-	-
Apr/90	362	54,670	-	-	-	-
May/90	319	46,650	-	-	-	-
Jun/90	353	53,930	-	-	-	-

Table 7b. Fatty and resin acids (ATG 26). Malette Kraft Pulp and Power Co. (Smooth Rock Falls). (Date: 3-5-1991).

Company: 0000860502 Cntr.pt.: 04	Prod. T/day	Bl.Prod T/day	Daily flow m3/day	Oleic acid g/tonne	Pimaric acid g/tonne	Abietic acid g/tonne	Dehydro-abietic acid g/tonne	Isopimaric acid g/tonne	Levopimaric acid g/tonne	Neoabietic acid g/tonne
Date										
Jan/90	340	340	46,730	-	6.7	72.8	203.4	61.8	-	11.1
Feb/90	335	335	48,960	-	6.9	71.6	49.9	36.5	1.5	13.3
Mar/90	300	300	50,060	-	14.0	110.1	32.1	86.8	-	23.2
Apr/90	362	362	54,670	-	-	6.3	16.8	8.2	3.8	1.2
May/90	319	319	46,650	-	3.2	6.9	25.2	6.1	-	-
Jun/90	353	353	53,930	-	5.2	-	42.1	6.3	-	-

Company: 0000860502 Cntr.pt.: 04	Prod. T/day	Bl.Prod T/day	Daily flow m3/day	Chlorodehydro abietic acid g/tonne	Dichlorodehydro abietic acid g/tonne	Total resin acids g/tonne	Total resin acids Kg/day	Total resin acids mg/l
Date								
Jan/90	340	340	46,730	15.3	19.7	371.2	126	2.70
Feb/90	335	335	48,960	8.5	23.2	188.2	63	1.29
Mar/90	300	300	50,060	7.7	19.8	273.9	82	1.64
Apr/90	362	362	54,670	6.5	12.1	42.7	15	0.28
May/90	319	319	46,650	10.7	7.1	52.1	17	0.36
Jun/90	353	353	53,930	6.4	34.1	60.0	21	0.39

Values for dehydroabietic acid and dichlorodehydroabietic acid are monthly averages

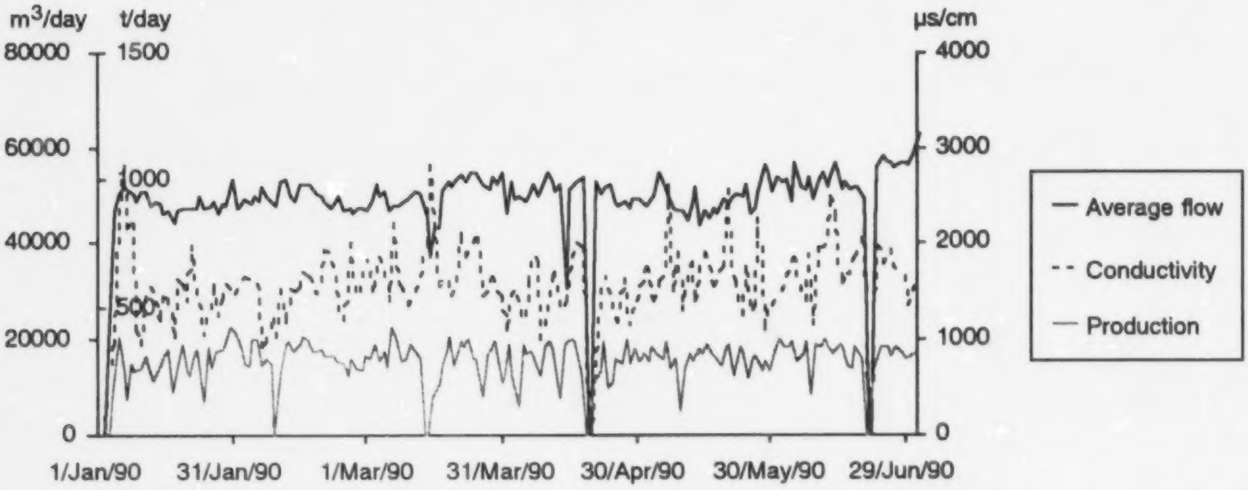
Table 6b. Metals (ATG 9 &12). Malette Kraft Pulp and Power Co. (Smooth Rock Falls). (Date: 3-5-1991).

Company 00008605C	Prod. T/day	Daily flow m3/day	Berylium g/tonne	Aluminium g/tonne	Copper g/tonne	Zinc g/tonne	Chromium g/tonne	Nickel g/tonne	Molybdenum g/tonne	Cobalt g/tonne
Date										
Jan/90	340	46,730	-	564	1.8	13.5	6.9	22.0	0.7	-
Feb/90	335	48,960	-	519	-	18.4	-	-	1.8	-
Mar/90	300	50,060	-	613	3.8	27.1	4.7	3.0	-	-
Apr/90	362	54,670	-	468	-	17.1	-	-	-	-
May/90	319	46,650	-	379	-	11.8	-	-	-	-
Jun/90	353	53,930	-	534	-	19.8	-	-	-	-

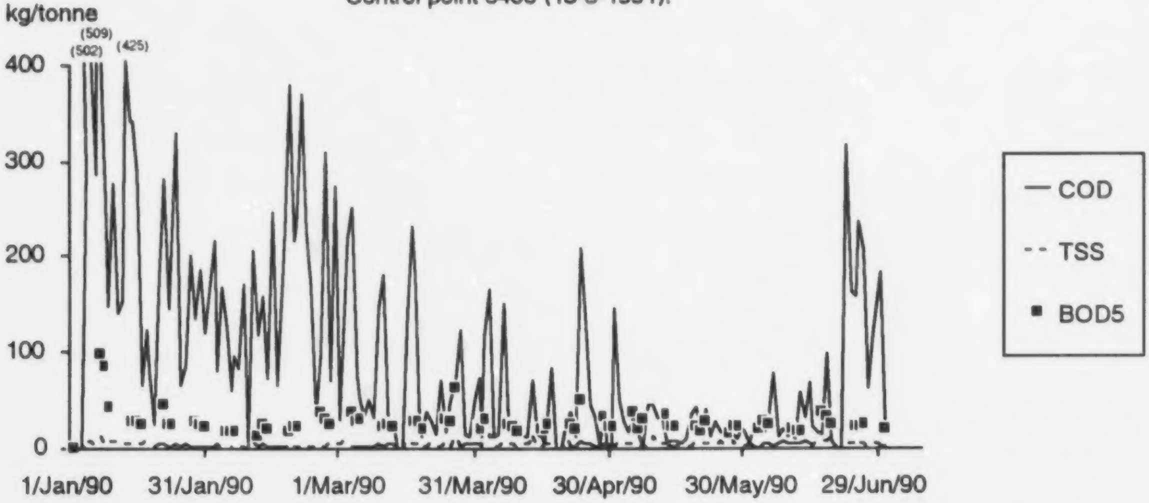
Company 00008605C	Prod. T/day	Daily flow m3/day	Vanadium g/tonne	Silver g/tonne	Lead g/tonne	Cadmium g/tonne	Thallium g/tonne	Mercury g/tonne
Date								
Jan/90	340	46,730	1.4	-	1.0	0.47	-	-
Feb/90	335	48,960	-	-	-	0.18	-	-
Mar/90	300	50,060	-	-	0.5	0.17	-	-
Apr/90	362	54,670	-	-	-	-	-	-
May/90	319	46,650	-	-	-	-	-	0.01
Jun/90	353	53,930	-	-	-	-	-	-

Values for aluminium and zink are monthly averages.

Average flow, Production and Conductivity data from Malette Kraft Pulp and Power Co. (Smooth Rock Falls), Control point 0400 (15-5-1991).



TSS, COD and BOD5 data from Malette Kraft Pulp and Power Co. (Smooth Rock Falls), Control point 0400 (15-5-1991).



Bl. Production and AOX data from Malette Kraft Pulp and Power Co. (Smooth Rock Falls) Control point 0400 (15-5-1991).

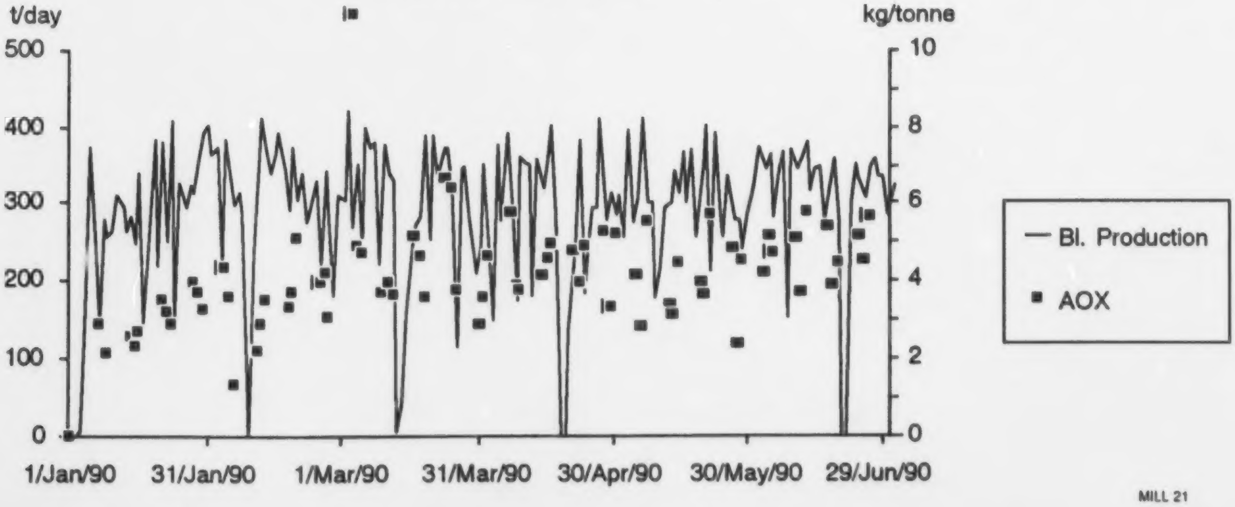


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Table 1b. Halogenated volatiles (ATG16). Abitibi-Price Inc., Thunder Bay Division. (Date: 25-4-1991).

Company 0000860007

Cntr pt 01	Prod T/day	Daily flow m3/day	Chloro-methane mg/tonne	Chloro-ethylene mg/tonne	Bromo-methane mg/tonne	Bromodi-chloromethane mg/tonne	Dichloro-methane mg/tonne	1,1-Dichloro-ethane mg/tonne	1,2-Dichloro-ethane mg/tonne	1,1-Dichloro-ethylene mg/tonne
Jan/90	475	44,765	-	-	-	-	415	-	-	-
Feb/90	494	46,287	337	-	-	-	637	-	-	-
Mar/90	239	41,236	8,627	-	-	-	1,639	-	-	-
Apr/90	459	46,177	-	-	2,616	-	153	-	-	-
May/90	486	42,593	-	-	-	-	29	-	-	-
Jun/90	484	44,205	-	-	-	-	-	-	-	-

Company 0000860007

Cntr pt 01	Prod T/day	Daily flow m3/day	trans-1,2-Di-chloroethylene mg/tonne	1,2-Dichloro-propane mg/tonne	cis-1,3-Di-chloropropylen mg/tonne	trans-1,3-Di-chloropropylen mg/tonne	Dibromo-ethylene mg/tonne	Trichloro-methane mg/tonne	Dibromo-chloromethane mg/tonne	Tribromo-methane mg/tonne	1,1,2-Tri-chloroethane mg/tonne
Jan/90	475	44,765	-	-	-	-	-	-	-	-	-
Feb/90	494	46,287	-	-	-	-	-	168	-	-	-
Mar/90	239	41,236	-	-	-	-	-	449	-	-	-
Apr/90	459	46,177	-	-	-	-	-	297	-	-	-
May/90	486	42,593	-	-	-	-	-	298	-	-	-
Jun/90	484	44,205	-	-	-	-	-	237	-	-	-

Company 0000860007

Cntr pt 01	Prod T/day	Daily flow m3/day	Trichloro-ethylene mg/tonne	Trifluoro-chloromethane mg/tonne	Tetrachloro-methane mg/tonne	1,1,2,2-Tetra-chloroethane mg/tonne	Tetrachloro-ethylene mg/tonne	Chloro-benzene mg/tonne	1,2-Dichloro-benzene mg/tonne	1,3-Dichloro-benzene mg/tonne	1,4-Dichloro-benzene mg/tonne
Jan/90	475	44,765	-	-	-	-	-	-	-	-	-
Feb/90	494	46,287	-	-	-	-	-	-	-	-	-
Mar/90	239	41,236	-	-	-	-	-	-	-	-	-
Apr/90	459	46,177	-	-	-	-	-	-	-	-	-
May/90	486	42,593	-	-	-	-	-	-	-	-	-
Jun/90	484	44,205	-	-	-	-	-	-	-	-	-

Table 2b. Nonhalogenated volatiles (ATG17). Abitibi-Price Inc., Thunder Bay Division. (Date: 25-4-1991).

Company: 0000860007

Cntr pt: 01 Date	Prod T/day	Daily flow m3/day	Styrene mg/tonne	Benzene mg/tonne	m,p-Xylene mg/tonne	o-Xylene mg/tonne	Toluene mg/tonne
Jan/90	475	44,765	-	556	-	-	-
Feb/90	494	46,287	-	562	-	-	42
Mar/90	239	41,236	-	-	-	-	93
Apr/90	459	46,177	-	30	-	-	53
May/90	486	42,593	-	-	-	-	79
Jun/90	484	44,205	-	-	-	-	60

Table 9b. Inorganics (ATG 3, 4, 6, 7 & 15). Abitibi-Price Inc., Thunder Bay Division. (Date: 25-4-1991).

Company: 0000860007

Cntr pt.: 01 Date	Prod T/day	Av. flow m3/day	pH	Conductivity µs/cm	NH3 + NH4 g/tonne	NO2+NO3 g/tonne	Total-N g/tonne	Total-P g/tonne	Sulphide g/tonne
Jan/90	481	46,309	5.0	653	4	34	181	18	-
Feb/90	485	45,570	5.2	626	5	25	131	18	-
Mar/90	461	44,541	5.1	632	4	34	121	15	-
Apr/90	453	41,326	5.3	659	5	27	163	17	-
May/90	470	44,711	4.8	790	6	16	209	26	-
Jun/90	479	47,411	4.4	741	6	15	184	23	-

Table 10b. Group and unspecific variables (ATG 1, 5, 8, PP1-3). Abitibi-Price Inc., Thunder Bay Division. (Date: 25-4-1991).

Company: 0000860007

Cntr pt.: 01 Date	Prod T/day	Av. flow m3/tonne	BOD5 Kg/tonne	AOX Kg/tonne	COD Kg/tonne	DOC Kg/tonne	TOC Kg/tonne	TSS Kg/tonne	VSS Kg/tonne	DOC/BOD
Jan/90	481	96.3	60.0	-	-	60.3	-	5.1	-	1.0
Feb/90	485	93.9	53.2	-	-	53.3	-	4.5	-	1.0
Mar/90	461	96.7	49.6	-	-	55.4	-	4.5	-	1.1
Apr/90	453	91.3	53.6	-	-	49.9	-	3.1	-	0.9
May/90	470	95.2	66.5	-	-	66.8	-	3.6	-	1.0
Jun/90	479	99.0	63.5	-	-	64.8	-	3.6	-	1.0

Table 3b. Extractable base neutrals (ATG10). Abitibi-Price Inc., Thunder Bay Division. (Date: 25-4-1991).

Company: 0000860007

Cntr.pt.: 01

Date	Prod. T/day	Daily flow m3/day	Naphthalene mg/tonne	1-Methyl-naphthalene mg/tonne	2-Methyl-naphthalene mg/tonne	1-Chloro-naphthalene mg/tonne	2-Chloro-naphthalene mg/tonne	Anthracene mg/tonne	Benz[a]-anthracene mg/tonne	Dibenz[a] anthracene mg/tonne
Jan/90	475	44,765	-	-	-	-	-	-	-	-
Feb/90	494	46,287	-	-	-	-	-	-	-	-
Mar/90	239	41,236	-	-	-	-	-	-	-	-
Apr/90	459	46,177	-	-	-	-	-	-	-	-
May/90	486	42,593	53	-	-	-	-	-	-	-
Jun/90	484	44,205	37	-	-	-	-	-	-	-

Company: 0000860007

Cntr.pt.: 01

Date	Prod. T/day	Daily flow m3/day	Phenan-threne mg/tonne	Acenaph-thene mg/tonne	Acenaph-thylene mg/tonne	5-Nitro-ace-naphthene mg/tonne	Chrysene mg/tonne	Fluor-anthene mg/tonne	Benz[b]-fluoranthene mg/tonne	Benz[k] fluoranthene mg/tonne	Fluorene mg/tonne
Jan/90	475	44,765	-	-	-	-	-	-	-	-	-
Feb/90	494	46,287	-	-	-	-	-	-	-	-	-
Mar/90	239	41,236	-	-	-	-	-	-	-	-	-
Apr/90	459	46,177	-	-	-	-	-	-	-	-	-
May/90	486	42,593	-	-	-	-	-	-	-	-	-
Jun/90	484	44,205	-	-	-	-	-	-	-	-	-

Company: 0000860007

Cntr.pt.: 01

Date	Prod. T/day	Daily flow m3/day	Pyrene mg/tonne	Benz[a]-pyrene mg/tonne	ideno[1,2,3-cd pyrene mg/tonne	Perylene mg/tonne	Benz[g,h,i]-perylene mg/tonne	Indole mg/tonne	Camphene mg/tonne
Jan/90	475	44,765	-	-	-	-	-	-	-
Feb/90	494	46,287	-	-	-	-	-	-	-
Mar/90	239	41,236	-	-	-	-	-	-	-
Apr/90	459	46,177	-	-	-	-	-	-	-
May/90	486	42,593	-	-	-	-	-	-	-
Jun/90	484	44,205	-	-	-	-	-	-	73

Table 4b. Acidic extractables (ATG20). Abitibi-Price Inc., Thunder Bay Division. (Date: 25-4-1991).

Company: 0000860007

Cntr.pt.: 01

Date	Prod. T/day	Daily flow m3/day	Phenol mg/tonne	m-Cresol mg/tonne	o-Cresol mg/tonne	p-Cresol mg/tonne	2,4-xylenol mg/tonne	4-Chloro-m-cresol mg/tonne	2-Chloro-phenol mg/tonne	2,4-Dichloro-phenol mg/tonne
Jan/90	475	44,765	-	-	-	-	-	-	-	-
Feb/90	494	46,287	-	-	-	-	-	-	-	-
Mar/90	239	41,236	569	690	-	-	-	-	-	-
Apr/90	459	46,177	392	412	-	845	-	-	-	-
May/90	486	42,593	316	245	-	202	-	-	-	-
Jun/90	484	44,205	247	374	-	265	-	-	-	-

Company: 0000860007

Cntr.pt.: 01

Date	Prod. T/day	Daily flow m3/day	2,6-Dichloro-phenol mg/tonne	2,3,4-Tri-chlorophenol mg/tonne	2,3,5-Tri-chlorophenol mg/tonne	2,4,5-Tri-chlorophenol mg/tonne	2,4,6-Tri-chlorophenol mg/tonne	2,3,4,5-Tetra-chlorophenol mg/tonne	2,3,4,6-Tetra-chlorophenol mg/tonne	2,3,5,6-Tetra-chlorophenol mg/tonne	Penta-chlorophenol mg/tonne
Jan/90	475	44,765	-	-	-	-	-	-	-	-	-
Feb/90	494	46,287	-	-	-	-	-	-	-	-	-
Mar/90	239	41,236	-	-	-	-	-	-	-	-	-
Apr/90	459	46,177	-	-	-	-	-	-	-	-	-
May/90	486	42,593	-	-	-	-	-	-	-	-	-
Jun/90	484	44,205	-	-	-	-	-	-	-	-	-

Company: 0000860007

Cntr.pt.: 01

Date	Prod. T/day	Daily flow m3/day	4-Nitro-phenol mg/tonne	2,4-Dinitro-phenol mg/tonne	4,6-Dinitro-o-cresol mg/tonne
Jan/90	475	44,765	-	-	-
Feb/90	494	46,287	1,387	-	-
Mar/90	239	41,236	-	-	-
Apr/90	459	46,177	2,817	-	-
May/90	486	42,593	2,016	-	-
Jun/90	484	44,205	-	-	-

Table 5b. Chlorinated, neutrals (ATG(23). Abitibi-Price Inc., Thunder Bay Division. (Date: 25-4-1991).

Company: 0000860007 Cntr.pt.: 01 Prod.	T/day	Daily flow m3/day	Hexachloro-ethane mg/tonne	Hexachloro-butadiene mg/tonne	Hexachloro-yclopentadien mg/tonne	1,2,3-Trichloro-benzene mg/tonne	1,2,4-Trichloro-benzene mg/tonne	2,4,5-Trichloro-toluene mg/tonne	1,2,3,4-Tetra-chlorobenzene mg/tonne	1,2,3,5-Tetra-chlorobenzene mg/tonne
Date										
Jan/90	475	44,765	-	-	-	-	-	-	-	-
Feb/90	494	46,287	-	-	-	-	-	-	-	-
Mar/90	239	41,236	-	-	-	-	-	-	-	-
Apr/90	459	46,177	-	-	-	-	-	-	-	-
May/90	486	42,593	-	-	-	-	-	-	-	-
Jun/90	484	44,205	-	-	-	-	-	-	-	-

Company: 0000860007 Cntr.pt.: 01 Prod.	T/day	Daily flow m3/day	1,2,4,5-Tetra-chlorobenzene mg/tonne	Penta-chlorobenzene mg/tonne	Hexa-chlorobenzene mg/tonne	Octachloro-styrene mg/tonne
Date						
Jan/90	475	44,765	1.0	-	-	-
Feb/90	494	46,287	-	-	0.5	-
Mar/90	239	41,236	-	-	-	-
Apr/90	459	46,177	-	-	-	-
May/90	486	42,593	-	-	-	-
Jun/90	484	44,205	-	-	-	-

Table 6b. Chlorinated dioxins, dibenzofuranes and PCB's (ATG(23). Abitibi-Price Inc., Thunder Bay Division. (Date: 25-4-1991).

Company: 0000860007 Cntr.pt.: 01 Prod.	T/day	Daily flow m3/day	2,3,7,8-TCDD µgtonne	Total TCDD µgtonne	Total TCDF µgtonne	Total PCDD µgtonne	Total PCDF µgtonne	Total HxCDD µgtonne	Total HxCDF µgtonne	Total HpCDD µgtonne
Date										
Feb/90	494	49,588	-	-	-	-	6.2	47.2	110.4	461.8
Apr/90	459	46,177	-	-	-	-	-	-	-	-
May/90	486	42,593	-	-	-	-	-	-	-	-
Jun/90	484	44,205	-	-	-	-	-	-	-	-
	-		-	-	-	-	-	-	-	-
	-		-	-	-	-	-	-	-	-

Company: 0000860007 Cntr.pt.: 01 Prod.	T/day	Daily flow m3/day	Total HpCDF µg/tonne	OCDD µg/tonne	OCDF µg/tonne	Total PCB's µg/tonne
Date						
Feb/90	494	49,588	371.4	1405.3	301.1	-
Apr/90	459	46,177	-	-	-	-
May/90	486	42,593	-	3.7	-	-
Jun/90	484	44,205	-	-	-	-
	-		-	-	-	-
	-		-	-	-	-

Table 7b. Fatty and resin acids (ATG 26). Abitibi-Price Inc., Thunder Bay Division. (Date: 25-4-1991).

Company: 0000860007 Cntr.pt.: 01 Prod.	T/day	Daily flow m3/day	Oleic acid g/tonne	Pimaric acid g/tonne	Abietic acid g/tonne	Dehydro-abietic acid g/tonne	Isopimaric acid g/tonne	Levopimaric acid g/tonne	Neoabietic acid g/tonne	Chlorodehydro-abietic acid g/tonne
Date										
Jan/90	475	44,765	-	23.6	110.3	140.6	110.3	17.4	19.8	-
Feb/90	494	46,287	4.6	32.8	160.2	138.7	161.2	51.5	54.3	-
Mar/90	239	41,236	-	-	414.1	237.9	-	34.5	-	-
Apr/90	459	46,177	2.1	7.3	110.7	114.3	34.2	10.6	11.1	-
May/90	486	42,593	1.8	5.5	75.4	166.5	25.4	6.0	7.4	-
Jun/90	484	44,205	23.7	24.7	392.7	182.9	105.0	-	54.8	-

Company: 0000860007 Cntr.pt.: 01 Prod.	T/day	Daily flow m3/day	Dichlorodehydr abietic acid g/tonne	Total resin acids g/tonne	Total resin acids Kg/day	Total resin acids <mg/l>
Date						
Jan/90	475	44,765	-	422	200	4.48
Feb/90	494	46,287	-	599	296	6.39
Mar/90	239	41,236	-	687	164	3.98
Apr/90	459	46,177	-	288	132	2.86
May/90	486	42,593	-	286	139	3.27
Jun/90	484	44,205	-	760	368	8.32

Values for dehydroabietic acid and dichlorodehydroabietic acid are monthly averages

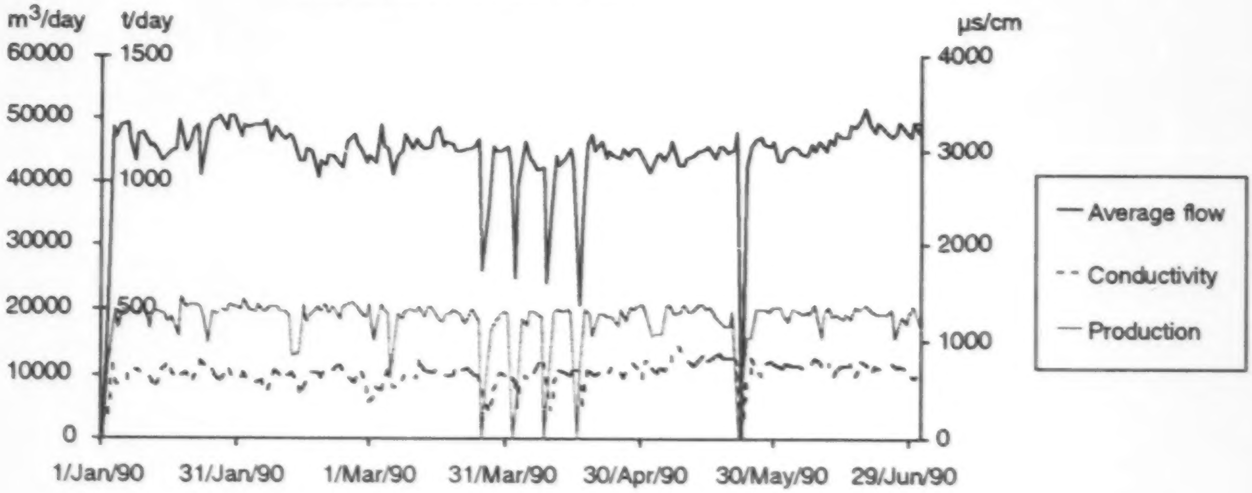
Table 8b. Metals (ATG 9 &12). Abitibi-Price Inc., Thunder Bay Division. (Date: 25-4-1991).

Company 00008600C Date	Prod. T/day	Daily flow m3/day	Berylium g/tonne	Aluminium g/tonne	Copper g/tonne	Zinc g/tonne	Chromium g/tonne	Nickel g/tonne	Molybdenum g/tonne	Cobalt g/tonne
Jan/90	475	44,765	-	98	0.9	4.6	-	-	-	-
Feb/90	494	46,287	-	86	-	6.2	-	-	-	-
Mar/90	239	41,236	-	181	-	10.7	-	-	-	-
Apr/90	459	46,177	-	88	0.9	7.2	-	-	-	-
May/90	486	42,593	-	101	-	5.0	-	-	-	-
Jun/90	484	44,205	-	119	-	5.9	-	-	-	-

Company 00008600C Date	Prod. T/day	Daily flow m3/day	Vanadium g/tonne	Silver g/tonne	Lead g/tonne	Cadmium g/tonne	Thallium g/tonne	Mercury g/tonne
Jan/90	475	44,765	0.6	-	0.4	0.04	-	-
Feb/90	494	46,287	-	-	-	0.05	-	-
Mar/90	239	41,236	-	-	0.3	0.09	-	-
Apr/90	459	46,177	17.1	-	1.5	0.80	-	-
May/90	486	42,593	-	-	-	-	-	-
Jun/90	484	44,205	-	-	-	-	-	-

Values for aluminium and zink are monthly averages.

Average flow, Production and Conductivity data from Abitibi-Price Inc., Thunder Bay Division, Control point 0100 (9-5-1991).



TSS, DOC and BOD5 data from Abitibi-Price Inc., Thunder Bay Division, Control point 0100 (9-5-1991).

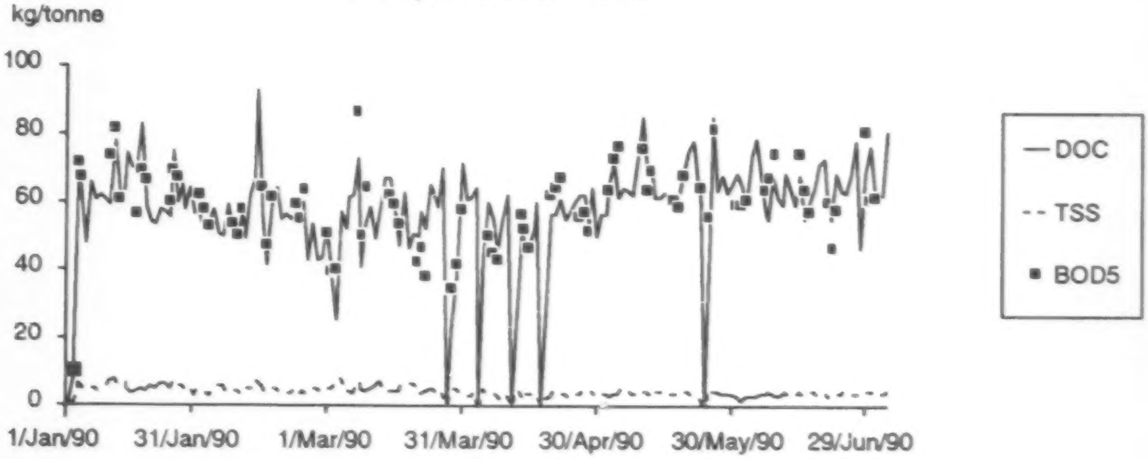


Table 1b. Halogenated volatiles (ATG16). Abitibi-Price Inc., Fort William Division.. (Date: 25-4-1991).

Company: 0000860205

Cntr.pt.: 01 Prod.	T/day	Daily flow m3/day	Chloromethane mg/tonne	Chloroethylene mg/tonne	Bromomethane mg/tonne	Bromodichloromethane mg/tonne	Dichloromethane mg/tonne	1,1-Dichloroethane mg/tonne	1,2-Dichloroethane mg/tonne	1,1-Dichloroethylene mg/tonne
Jan/90	329	25,449	138.9	-	-	-	353.7	15.6	-	-
Feb/90	360	27,362	-	-	51.8	-	1524.9	-	-	-
Mar/90	385	25,393	300.5	-	-	-	1691.0	-	-	-
Apr/90	261	24,449	13.6	-	44.0	-	897.1	-	-	-
May/90	387	25,373	-	-	-	-	-	-	-	-
Jun/90	410	20,208	-	-	-	-	-	-	-	-

Company: 0000860205

Cntr.pt.: 01 Prod.	T/day	Daily flow m3/day	trans-1,2-Dichloroethylene mg/tonne	1,2-Dichloropropane mg/tonne	cis-1,3-Dichloropropylene mg/tonne	trans-1,3-Dichloropropylene mg/tonne	Dibromoethylene mg/tonne	Trichloromethane mg/tonne	Dibromochloromethane mg/tonne	Tribromomethane mg/tonne	1,1,2-Trichloroethane mg/tonne
Jan/90	329	25,449	-	-	-	-	-	2087.8	-	-	-
Feb/90	360	27,362	-	-	-	-	-	2627.0	-	-	-
Mar/90	385	25,393	-	-	-	-	-	1577.3	-	-	-
Apr/90	261	24,449	-	-	-	-	-	2093.5	-	-	-
May/90	387	25,373	-	-	-	-	-	2106.9	-	-	-
Jun/90	410	20,208	-	-	-	-	-	473.2	-	-	-

Company: 0000860205

Cntr.pt.: 01 Prod.	T/day	Daily flow m3/day	Trichloroethylene mg/tonne	Trifluorochloromethane mg/tonne	Tetrachloromethane mg/tonne	1,1,2,2-Tetrachloroethane mg/tonne	Tetrachloroethylene mg/tonne	Chlorobenzene mg/tonne	1,2-Dichlorobenzene mg/tonne	1,3-Dichlorobenzene mg/tonne	1,4-Dichlorobenzene mg/tonne
Jan/90	329	25,449	-	-	-	-	-	-	-	-	-
Feb/90	360	27,362	-	-	-	-	-	-	-	-	-
Mar/90	385	25,393	-	-	-	-	-	-	-	-	-
Apr/90	261	24,449	-	-	-	-	-	-	-	-	-
May/90	387	25,373	-	-	-	-	-	-	-	-	-
Jun/90	410	20,208	-	-	-	-	-	-	-	-	-

Table 2b. Nonhalogenated volatiles (ATG17). Abitibi-Price Inc., Fort William Division.. (Date: 25-4-1991).

Company: 0000860205

Cntr.pt.: 01 Prod. Date	T/day	Daily flow m3/day	Styrene mg/tonne	Benzene mg/tonne	m,p-Xylene mg/tonne	o-Xylene mg/tonne	Toluene mg/tonne
Jan/90	329	25,449	-	38	-	-	431
Feb/90	360	27,362	6	-	41	31	496
Mar/90	385	25,393	-	-	2	5	255
Apr/90	261	24,449	-	196	25	3	683
May/90	387	25,373	-	-	-	-	453
Jun/90	410	20,208	-	-	-	-	434

Table 9b. Inorganics (ATG 3, 4, 6, 7 & 15). Abitibi-Price Inc., Fort William Division.. (Date: 25-4-1991).

Company: 0000860205

Cntr.pt.: 01 Prod. Date	T/day	Av. flow m3/day	pH	Conductivity µs/cm	NH3 + NH4 g/tonne	NO2+NO3 g/tonne	Total-N g/tonne	Total-P g/tonne	Sulphide g/tonne
Jan/90	348	25,679	6.7	832	7	6	177	51	-
Feb/90	387	25,994	6.6	925	5	3	158	13	-
Mar/90	349	26,074	6.8	914	9	4	207	27	-
Apr/90	359	24,584	6.6	960	9	5	209	37	-
May/90	399	25,599	6.6	1060	9	5	230	36	-
Jun/90	388	22,080	6.6	1015	8	5	205	23	-

Table 10b. Group and unspecific variables (ATG 1, 5, 8, PP1-3). Abitibi-Price Inc., Fort William Division.. (Date: 25-4-1991).

Company: 0000860205

Cntr.pt.: 01 Prod. Date	T/day	Av. flow m3/tonne	BOD5 Kg/tonne	AOX Kg/tonne	COD Kg/tonne	DOC Kg/tonne	TOC Kg/tonne	TSS Kg/tonne	VSS Kg/tonne	DOC/BOD
Jan/90	348	74	36.7	-	-	26.2	-	3.2	-	0.7
Feb/90	387	67	38.9	-	-	26.6	-	3.2	-	0.7
Mar/90	349	75	42.7	-	-	29.6	-	3.6	-	0.7
Apr/90	359	68	39.9	-	-	26.5	-	3.1	-	0.7
May/90	399	64	38.4	-	-	26.3	-	3.1	-	0.7
Jun/90	388	57	23.8	-	-	22.1	-	1.8	-	0.9

Table 3b. Extractable base neutrals (ATG19). Abitibi-Price Inc., Fort William Division.. (Date: 25-4-1991).

Company: 0000860205
Cntr pt.: 01

Date	Prod T/day	Daily flow m3/day	Naphthalene mg/tonne	1-Methyl-naphthalene mg/tonne	2-Methyl-naphthalene mg/tonne	1-Chloro-naphthalene mg/tonne	2-Chloro-naphthalene mg/tonne	Anthracene mg/tonne	Benz[a]-anthracene mg/tonne	Dibenz[a] anthracene mg/tonne
Jan/90	329	25,449	-	-	-	-	-	-	-	-
Feb/90	360	27,362	-	-	-	-	-	-	-	-
Mar/90	385	25,393	-	-	-	-	-	-	-	-
Apr/90	261	24,449	-	-	-	-	-	-	-	-
May/90	387	25,373	3	-	-	-	-	-	-	-
Jun/90	410	20,208	-	-	-	-	-	-	-	-

Company: 0000860205
Cntr pt.: 01

Date	Prod T/day	Daily flow m3/day	Phenanthrene mg/tonne	Acenaphthene mg/tonne	Acenaphthylene mg/tonne	5-Nitro-acenaphthene mg/tonne	Chrysene mg/tonne	Fluoranthene mg/tonne	Benz[b]-fluoranthene mg/tonne	Benz[k] fluoranthene mg/tonne	Fluorene mg/tonne
Jan/90	329	25,449	-	-	-	-	-	-	-	-	-
Feb/90	360	27,362	-	-	-	-	-	-	-	-	-
Mar/90	385	25,393	-	-	-	-	-	-	-	-	-
Apr/90	261	24,449	-	-	-	-	-	-	-	-	-
May/90	387	25,373	-	6	12	-	-	-	-	-	-
Jun/90	410	20,208	-	-	-	-	-	-	-	-	-

Company: 0000860205
Cntr pt.: 01

Date	Prod T/day	Daily flow m3/day	Pyrene mg/tonne	Benz[a]-pyrene mg/tonne	ideno[1,2,3-cd pyrene mg/tonne	Perylene mg/tonne	Benz[g,h,i]-perylene mg/tonne	Indole mg/tonne	Camphene mg/tonne
Jan/90	329	25,449	-	-	-	-	-	-	-
Feb/90	360	27,362	-	-	-	-	-	-	88
Mar/90	385	25,393	-	-	-	-	-	-	70
Apr/90	261	24,449	-	-	-	-	-	-	130
May/90	387	25,373	-	-	-	-	-	-	-
Jun/90	410	20,208	-	-	-	-	-	163	30

Table 4b. Acidic extractables (ATG20). Abitibi-Price Inc., Fort William Division.. (Date: 25-4-1991).

Company: 0000860205
Cntr pt.: 01

Date	Prod T/day	Daily flow m3/day	Phenol mg/tonne	m-Cresol mg/tonne	o-Cresol mg/tonne	p-Cresol mg/tonne	2,4-xylenol mg/tonne	4-Chloro-m-cresol mg/tonne	2-Chloro-phenol mg/tonne	2,4-Dichloro-phenol mg/tonne
Jan/90	329	25,449	1,405	309	-	1,391	-	-	-	-
Feb/90	360	27,362	1,880	836	-	699	-	-	-	-
Mar/90	385	25,393	1,394	634	-	466	-	-	-	-
Apr/90	261	24,449	660	444	48	492	-	-	-	-
May/90	387	25,373	1,210	382	9	704	-	-	-	-
Jun/90	410	20,208	1,774	138	-	380	-	-	-	-

Company: 0000860205
Cntr pt.: 01

Date	Prod T/day	Daily flow m3/day	2,6-Dichloro-phenol mg/tonne	2,3,4-Tri-chlorophenol mg/tonne	2,3,5-Tri-chlorophenol mg/tonne	2,4,5-Tri-chlorophenol mg/tonne	2,4,6-Tri-chlorophenol mg/tonne	2,3,4,5-Tetra-chlorophenol mg/tonne	2,3,4,6-Tetra-chlorophenol mg/tonne	2,3,5,6-Tetra-chlorophenol mg/tonne	Penta-chlorophenol mg/tonne
Jan/90	329	25,449	-	-	-	-	-	-	-	-	-
Feb/90	360	27,362	-	-	-	-	81	-	-	-	-
Mar/90	385	25,393	-	-	-	-	85	-	-	-	-
Apr/90	261	24,449	-	-	-	-	-	-	-	-	-
May/90	387	25,373	-	-	-	-	-	-	-	-	-
Jun/90	410	20,208	-	-	-	-	-	-	-	-	-

Company: 0000860205
Cntr pt.: 01

Date	Prod T/day	Daily flow m3/day	4-Nitro-phenol mg/tonne	2,4-Dinitro-phenol mg/tonne	4,6-Dinitro-o-cresol mg/tonne
Jan/90	329	25,449	-	-	-
Feb/90	360	27,362	-	-	-
Mar/90	385	25,393	-	-	-
Apr/90	261	24,449	-	-	-
May/90	387	25,373	141	-	-
Jun/90	410	20,208	212	-	-

Table 5b. Chlorinated, neutrals (ATG(23). Abitibi-Price Inc., Fort William Division.. (Date: 25-4-1991).

Company: 0000860205

Cntr pt.: 01 Date	Prod T/day	Daily flow m3/day	Hexachloro- ethane mg/tonne	Hexachloro- butadiene mg/tonne	Hexachloro- cyclopentadien mg/tonne	1,2,3-Trichloro- benzene mg/tonne	1,2,4-Trichloro- benzene mg/tonne	2,4,5-Trichloro- toluene mg/tonne	1,2,3,4-Tetra- chlorobenzene mg/tonne	1,2,3,5-Tetra- chlorobenzene mg/tonne
Jan/90	329	25,449	-	-	-	-	-	-	-	-
Feb/90	360	27,362	-	-	-	-	-	-	-	-
Mar/90	385	25,393	-	-	-	-	-	-	-	-
Apr/90	261	24,449	-	-	-	-	-	-	-	-
May/90	387	25,373	-	-	-	-	-	-	-	-
Jun/90	410	20,208	-	-	-	-	-	-	-	-

Company: 0000860205

Cntr pt.: 01 Date	Prod T/day	Daily flow m3/day	1,2,4,5-Tetra- chlorobenzene mg/tonne	Penta- chlorobenzene mg/tonne	Hexa- chlorobenzene mg/tonne	Octachloro- styrene mg/tonne
Jan/90	329	25,449	-	-	-	-
Feb/90	360	27,362	-	-	-	-
Mar/90	385	25,393	-	-	-	-
Apr/90	261	24,449	-	-	-	-
May/90	387	25,373	-	-	-	-
Jun/90	410	20,208	-	-	-	-

Table 6b. Chlorinated dioxins, dibenzofuranes and PCB's (ATG(23). Abitibi-Price Inc., Fort William Division. (Date: 25-4-1991)

Company: 0000860205

Cntr pt.: 01 Date	Prod T/day	Daily flow m3/day	2,3,7,8-TCDD µg/tonne	Total TCDD µg/tonne	Total TCDF µg/tonne	Total PCDD µg/tonne	Total PCDF µg/tonne	Total HxCDD µg/tonne	Total HxCDF µg/tonne	Total HpCDD µg/tonne
Feb/90	356	26,545	-	-	-	-	-	-	-	-
Apr/90	261	24,449	-	-	-	-	-	-	-	-
Jun/90	410	20,208	-	-	-	-	-	-	-	-

Company: 0000860205

Cntr pt.: 01 Date	Prod T/day	Daily flow m3/day	Total HpCDF µg/tonne	OCDD µg/tonne	OCDF µg/tonne	Total PCB's µg/tonne
Feb/90	356	26,545	-	6.1	-	-
Apr/90	261	24,449	-	7.3	-	-
Jun/90	410	20,208	-	-	-	-

Table 7b. Fatty and resin acids (ATG 26). Abitibi-Price Inc., Fort William Division.. (Date: 25-4-1991).

Company: 0000860205

Cntr pt.: 01 Date	Prod T/day	Daily flow m3/day	Oleic acid g/tonne	Pimaric acid g/tonne	Abietic acid g/tonne	Dehydro- abietic acid g/tonne	Isopimaric acid g/tonne	Levopimaric acid g/tonne	Neoabietic acid g/tonne	Chlorodehydro- abietic acid g/tonne
Jan/90	329	25,449	7.2	44.8	203.5	235.6	244.8	36.3	26.5	-
Feb/90	360	27,362	12.2	48.7	205.7	290.0	211.2	6.1	54.8	-
Mar/90	385	25,393	18.7	115.9	468.5	239.4	375.1	22.1	58.5	-
Apr/90	261	24,449	5.1	18.1	212.1	303.1	71.5	18.9	27.1	2.4
May/90	387	25,373	3.[illegible]	19.1	198.2	222.8	93.4	21.2	34.7	-
Jun/90	410	20,208	4.8	32.0	197.2	187.1	231.7	23.7	23.2	-

Company: 0000860205

Cntr pt.: 01 Date	Prod T/day	Daily flow m3/day	Dichlorodehydro- abietic acid g/tonne	Total resin acids g/tonne	Total resin acids Kg/day	Total resin acids <mg/l>
Jan/90	329	25,449	-	791.6	260	10.23
Feb/90	360	27,362	-	816.2	294	10.74
Mar/90	385	25,393	-	1279.8	493	19.40
Apr/90	261	24,449	-	653.2	170	6.97
May/90	387	25,373	-	589.5	228	8.99
Jun/90	410	20,208	-	694.8	285	14.10

Values for dehydroabietic acid and dichlorodehydroabietic acid are monthly averages

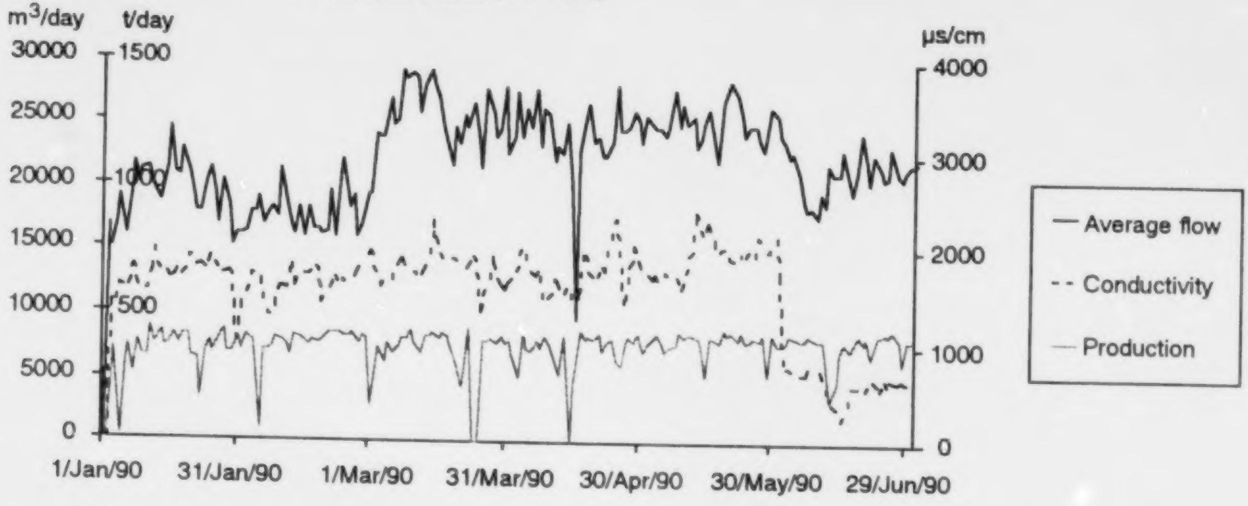
Table 8b. Metals (ATG 9 &12). Abitibi-Price Inc., Fort William Division.. (Date: 25-4-1991).

Company 00008602C	Prod T/day	Daily flow m3/day	Berylium g/tonne	Aluminium g/tonne	Copper g/tonne	Zinc g/tonne	Chromium g/tonne	Nickel g/tonne	Molybdenum g/tonne	Cobalt g/tonne
Date										
Jan/90	329	25,449	-	31	1	4	2	-	-	-
Feb/90	360	27,362	-	22	-	5	-	-	-	-
Mar/90	385	25,393	-	28	1	5	1	-	-	-
Apr/90	261	24,449	-	139	26	6	-	-	-	-
May/90	387	25,373	-	54	-	5	1	1	-	-
Jun/90	410	20,208	-	19	-	2	-	-	-	-

Company 00008602C	Prod T/day	Daily flow m3/day	Vanadium g/tonne	Silver g/tonne	Lead g/tonne	Cadmium g/tonne	Thallium g/tonne	Mercury g/tonne
Date								
Jan/90	329	25,449	-	-	-	-	-	-
Feb/90	360	27,362	-	-	-	-	-	-
Mar/90	385	25,393	-	-	-	-	-	-
Apr/90	261	24,449	1	-	-	-	-	-
May/90	387	25,373	-	-	-	-	-	-
Jun/90	410	20,208	1	-	-	-	-	-

Values for aluminium and zink are monthly averages

Average flow, Production and Conductivity data from Abitibi-Price Inc., Fort William Division., Control point 0200 (4-5-1991).



TSS, DOC and BOD5 data from Abitibi-Price Inc., Fort William Division., Control point 0100 (4-5-1991).

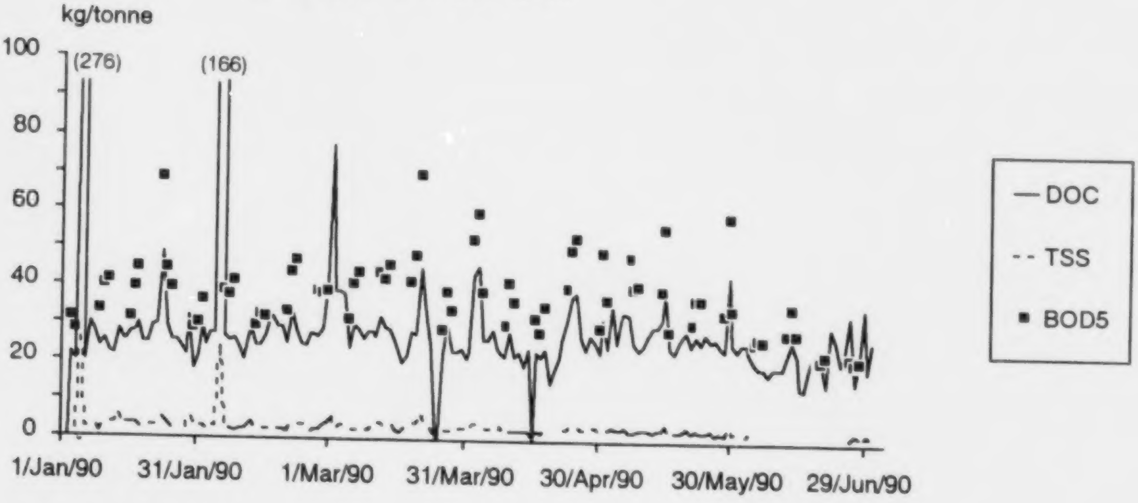


Table 1b. Halogenated volatiles (ATG16). Abitibi-Price Inc., Provincial Papers Division. (Date: 25-4-1991).

Company 0000860106 Cntr pt 01	Prod T/day	Daily flow m3/day	Chloro-methane mg/tonne	Chloro-ethylene mg/tonne	Bromo-methane mg/tonne	Bromodi-chloromethane mg/tonne	Dichloro-methane mg/tonne	1,1-Dichloro-ethane mg/tonne	1,2-Dichloro-ethane mg/tonne	1,1-Dichloro-ethylene mg/tonne
Jan/90	417	44,292	-	-	-	-	1,625	-	-	-
Feb/90	340	55,079	-	-	-	-	3,110	-	-	-
Mar/90	433	49,167	-	-	647	-	136	-	-	-
Apr/90	451	47,520	1,233	-	207	-	685	-	-	-
May/90	475	40,232	-	-	-	-	-	-	-	-
Jun/90	286	41,558	-	-	-	-	3,342	-	-	-

Company 0000860106 Cntr pt 01	Prod T/day	Daily flow m3/day	trans-1,2-Di-chloroethylene mg/tonne	1,2-Dichloro-propane mg/tonne	cis-1,3-Di-chloropropylene mg/tonne	trans-1,3-Di-chloropropylene mg/tonne	Dibromo-ethylene mg/tonne	Trichloro-methane mg/tonne	Dibromo-chloromethane mg/tonne	Tribromo-methane mg/tonne	1,1,2-Tri-chloroethane mg/tonne
Jan/90	417	44,292	-	-	-	-	-	414	-	-	-
Feb/90	340	55,079	-	-	-	-	-	518	-	-	-
Mar/90	433	49,167	-	-	-	-	-	500	-	-	-
Apr/90	451	47,520	-	-	-	-	-	211	-	-	-
May/90	475	40,232	-	-	-	-	-	855	-	-	0
Jun/90	286	41,558	-	-	-	-	-	567	-	-	-

Company 0000860106 Cntr pt 01	Prod T/day	Daily flow m3/day	Trichloro-ethylene mg/tonne	Trifluoro-chloromethane mg/tonne	Tetrachloro-methane mg/tonne	1,1,2,2-Tetra-chloroethane mg/tonne	Tetrachloro-ethylene mg/tonne	Chloro-benzene mg/tonne	1,2-Dichloro-benzene mg/tonne	1,3-Dichloro-benzene mg/tonne	1,4-Dichloro-benzene mg/tonne
Jan/90	417	44,292	-	-	-	-	-	-	-	-	-
Feb/90	340	55,079	-	-	-	-	-	-	-	-	-
Mar/90	433	49,167	-	-	-	-	-	-	-	-	-
Apr/90	451	47,520	-	-	-	-	-	30	-	-	-
May/90	475	40,232	-	-	-	-	-	-	-	-	-
Jun/90	286	41,558	-	-	-	-	-	-	-	-	-

Table 2b. Nonhalogenated volatiles (ATG17). Abitibi-Price Inc., Provincial Papers Division. (Date: 25-4-1991).

Company 0000860106

Cntr pt 01 Date	Prod T/day	Daily flow m3/day	Styrene mg/tonne	Benzene mg/tonne	m,p-Xylene mg/tonne	o-Xylene mg/tonne	Toluene mg/tonne
Jan/90	417	44,292	132	329	23	40	58
Feb/90	340	55,079	207	1037	49	52	-
Mar/90	433	49,167	109	73	47	60	106
Apr/90	451	47,520	77	123	26	32	46
May/90	475	40,232	102	-	153	136	92
Jun/90	286	41,558	-	-	7992	2790	99

Table 9b. Inorganics (ATG 3, 4, 6, 7 & 15). Abitibi-Price Inc., Provincial Papers Division. (Date: 25-4-1991

Company 0000860106

Cntr pt 01 Date	Prod T/day	Av flow m3/day	pH	Conductivity µs/cm	NH3 + NH4 g/tonne	NO2+NO3 g/tonne	Total-N g/tonne	Total-P g/tonne	Sulphide g/tonne
Jan/90	407	51,404	7.6	382	85	44	228	6	-
Feb/90	398	53,243	7.0	356	24	33	124	10	-
Mar/90	435	49,687	6.8	321	30	40	110	12	-
Apr/90	436	45,094	6.9	335	36	30	116	7	-
May/90	427	41,933	7.0	360	5	29	82	8	-
Jun/90	435	42,229	7.0	352	35	31	153	8	-

Table 10b. Group and unspecific variables (ATG 1, 5, 8, PP1-3). Abitibi-Price Inc., Provincial Papers Division. (Date: 25-4-1991)

Company 0000860106

Cntr.pt.: 01 Date	Prod. T/day	Av. flow m3/tonne	BOD5 Kg/tonne	AOX Kg/tonne	COD Kg/tonne	DOC Kg/tonne	TOC Kg/tonne	TSS Kg/tonne	VSS Kg/tonne	DOC/BOD
Jan/90	407	126	9.6	-	-	6.7	-	6.8	-	0.7
Feb/90	398	134	10.9	-	-	6.9	-	4.2	-	0.6
Mar/90	435	114	8.7	-	-	6.6	-	2.9	-	0.8
Apr/90	436	103	8.4	-	-	5.9	-	2.5	-	0.7
May/90	427	98	10.0	-	-	7.8	-	3.3	-	0.8
Jun/90	435	97	10.7	-	-	7.3	-	3.4	-	0.7

Table 3b. Extractable base neutrals (ATG19). Abitibi-Price Inc., Provincial Papers Division. (Date: 25-4-1991).

Company: 0000860106 Cntr pt.: 01 Date	Prod T/day	Daily flow m3/day	Naphthalene mg/tonne	1-Methyl-naphthalene mg/tonne	2-Methyl-naphthalene mg/tonne	1-Chloro-naphthalene mg/tonne	2-Chloro-naphthalene mg/tonne	Anthracene mg/tonne	Benz[a]-anthracene mg/tonne	Dibenz[a] anthracene mg/tonne
Jan/90	417	44,292	-	-	-	-	-	-	-	-
Feb/90	340	55,079	-	-	-	-	-	-	-	-
Mar/90	433	49,167	-	-	-	-	-	-	-	-
Apr/90	451	47,520	-	-	-	-	-	-	-	-
May/90	475	40,232	102	76	76	-	-	-	-	-
Jun/90	286	41,558	160	44	44	-	-	-	-	-

Company: 0000860106 Cntr pt.: 01 Date	Prod T/day	Daily flow m3/day	Phenan-threne mg/tonne	Acenaph-thene mg/tonne	Acenaph-thylene mg/tonne	5-Nitro-ace-naphthene mg/tonne	Chrysene mg/tonne	Fluor-anthene mg/tonne	Benz[b]-fluoranthene mg/tonne	Benz[k] fluoranthene mg/tonne	Fluorene mg/tonne
Jan/90	417	44,292	-	-	-	-	-	-	-	-	-
Feb/90	340	55,079	-	-	-	-	-	-	-	-	-
Mar/90	433	49,167	-	-	-	-	-	-	-	-	-
Apr/90	451	47,520	-	-	-	-	-	-	-	-	-
May/90	475	40,232	-	-	-	-	-	-	-	-	-
Jun/90	286	41,558	-	-	-	-	-	-	-	-	-

Company: 0000860106 Cntr pt.: 01 Date	Prod T/day	Daily flow m3/day	Pyrene mg/tonne	Benz[a]-pyrene mg/tonne	ideno[1,2,3-cd pyrene mg/tonne	Perylene mg/tonne	Benz[g,h,i]-perylene mg/tonne	Indole mg/tonne	Camphene mg/tonne
Jan/90	417	44,292	-	-	-	-	-	-	-
Feb/90	340	55,079	-	-	-	-	-	-	-
Mar/90	433	49,167	-	-	-	-	-	-	-
Apr/90	451	47,520	-	-	-	-	-	-	-
May/90	475	40,232	-	-	-	-	-	-	-
Jun/90	286	41,558	-	-	-	-	-	87	-

Table 4b. Acidic extractables (ATG20). Abitibi-Price Inc., Provincial Papers Division. (Date: 25-4-1991).

Company: 0000860106 Cntr pt.: 01 Date	Prod T/day	Daily flow m3/day	Phenol mg/tonne	m-Cresol mg/tonne	o-Cresol mg/tonne	p-Cresol mg/tonne	2,4-xylenol mg/tonne	4-Chloro-m-cresol mg/tonne	2-Chloro-phenol mg/tonne	2,4-Dichloro-phenol mg/tonne
Jan/90	417	44,292	-	-	-	-	-	-	-	-
Feb/90	340	55,079	-	-	-	-	-	-	-	-
Mar/90	433	49,167	-	198	-	201	-	-	-	-
Apr/90	451	47,520	263	-	-	-	-	-	-	-
May/90	475	40,232	-	-	-	-	-	-	-	-
Jun/90	286	41,558	58	160	-	407	-	-	-	-

Company: 0000860106 Cntr pt.: 01 Date	Prod T/day	Daily flow m3/day	2,6-Dichloro-phenol mg/tonne	2,3,4-Tri-chlorophenol mg/tonne	2,3,5-Tri-chlorophenol mg/tonne	2,4,5-Tri-chlorophenol mg/tonne	2,4,6-Tri-chlorophenol mg/tonne	2,3,4,5-Tetra-chlorophenol mg/tonne	2,3,4,6-Tetra-chlorophenol mg/tonne	2,3,5,6-Tetra-chlorophenol mg/tonne	Penta-chlorophenol mg/tonne
Jan/90	417	44,292	-	-	-	-	-	-	-	-	-
Feb/90	340	55,079	-	-	-	-	-	-	-	-	-
Mar/90	433	49,167	-	-	-	-	-	-	-	-	-
Apr/90	451	47,520	-	-	-	-	-	-	-	-	-
May/90	475	40,232	-	-	-	-	-	-	-	-	0
Jun/90	286	41,558	-	-	-	-	58	-	-	-	-

Company: 0000860106 Cntr pt.: 01 Date	Prod T/day	Daily flow m3/day	4-Nitro-phenol mg/tonne	2,4-Dinitro-phenol mg/tonne	4,6-Dinitro-o-cresol mg/tonne
Jan/90	417	44,292	-	-	-
Feb/90	340	55,079	-	-	-
Mar/90	433	49,167	-	-	-
Apr/90	451	47,520	-	-	-
May/90	475	40,232	-	-	-
Jun/90	286	41,558	-	-	-

Table 5b. Chlorinated, neutrals (ATG(23). Abitibi-Price Inc., Provincial Papers Division. (Date: 25-4-1991).

Company: 0000860106 Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	Hexachloro-ethane mg/tonne	Hexachloro-butadiene mg/tonne	Hexachloro-yclopentadien mg/tonne	1,2,3-Trichloro-benzene mg/tonne	1,2,4-Trichloro-benzene mg/tonne	2,4,5-Trichloro-toluene mg/tonne	1,2,3,4-Tetra-chlorobenzene mg/tonne	1,2,3,5-Tetra-chlorobenzene mg/tonne
Date										
Jan/90	417	44,292	-	-	-	-	-	-	-	-
Feb/90	340	55,079	-	-	-	-	-	-	-	-
Mar/90	433	49,167	-	-	-	-	-	0.3	-	-
Apr/90	451	47,520	-	-	-	-	-	-	-	-
May/90	475	40,232	-	-	-	-	-	-	-	-
Jun/90	286	41,558	-	-	-	-	-	-	-	-

Company: 0000860106 Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	1,2,4,5-Tetra-chlorobenzene mg/tonne	Penta-chlorobenzene mg/tonne	Hexa-chlorobenzene mg/tonne	Octachloro-styrene mg/tonne
Date						
Jan/90	417	44,292	-	-	-	-
Feb/90	340	55,079	-	-	-	-
Mar/90	433	49,167	-	-	-	-
Apr/90	451	47,520	-	-	-	-
May/90	475	40,232	-	-	-	-
Jun/90	286	41,558	-	-	-	-

Table 6b. Chlorinated dioxins, dibenzofuranes and PCB's (ATG(23). Abitibi-Price Inc., Provincial Papers Division. (Date: 25-4-1991).

Company: 0000860106 Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	2,3,7,8-TCDD µgtonne	Total TCDD µgtonne	Total TCDF µgtonne	Total PCDD µgtonne	Total PCDF µgtonne	Total HxCDD µgtonne	Total HxCDF µgtonne	Total HpCDD µgtonne
Date										
Jun/90	286	41,558	-	-	-	-	-	-	-	-
	-		-	-	-	-	-	-	-	-
	-		-	-	-	-	-	-	-	-
	-		-	-	-	-	-	-	-	-
	-		-	-	-	-	-	-	-	-
	-		-	-	-	-	-	-	-	-

Company: 0000860106 Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	Total HpCDF µg/tonne	OCDD µg/tonne	OCDF µg/tonne	Total PCB's µg/tonne
Date						
Jun/90	286	41,558	-	-	-	-
	-		-	-	-	-
	-		-	-	-	-
	-		-	-	-	-
	-		-	-	-	-
	-		-	-	-	-

Table 7b. Fatty and resin acids (ATG 26). Abitibi-Price Inc., Provincial Papers Division. (Date: 25-4-1991).

Company: 0000860106 Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	Oleic acid g/tonne	Pimaric acid g/tonne	Abietic acid g/tonne	Dehydro-abietic acid g/tonne	Isopimaric acid g/tonne	Levopimaric acid g/tonne	Neoabietic acid g/tonne	Chlorodehydro-abietic acid g/tonne
Date										
Jan/90	417	44,292	-	-	2.0	29.5	4.4	-	-	-
Feb/90	340	55,079	13.0	7.6	10.7	63.9	19.4	-	-	-
Mar/90	433	49,167	-	-	5.7	31.5	5.2	-	-	-
Apr/90	451	47,520	-	-	0.9	28.6	0.8	-	-	-
May/90	475	40,232	-	-	-	40.2	1.6	-	-	-
Jun/90	286	41,558	-	2.5	-	78.4	7.3	-	-	1.9

Company: 0000860106 Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	Dichlorodehydr abietic acid g/tonne	Total resin acids g/tonne	Total resin acids Kg/day	Total resin acids <mg/l>
Date						
Jan/90	417	44,292	-	35.9	15	0.34
Feb/90	340	55,079	-	101.7	35	0.63
Mar/90	433	49,167	-	42.4	18	0.37
Apr/90	451	47,520	-	30.4	14	0.29
May/90	475	40,232	-	41.8	20	0.49
Jun/90	286	41,558	-	90.0	26	0.62

Values for dehydroabietic acid and dichlorodehydroabietic acid are monthly averages

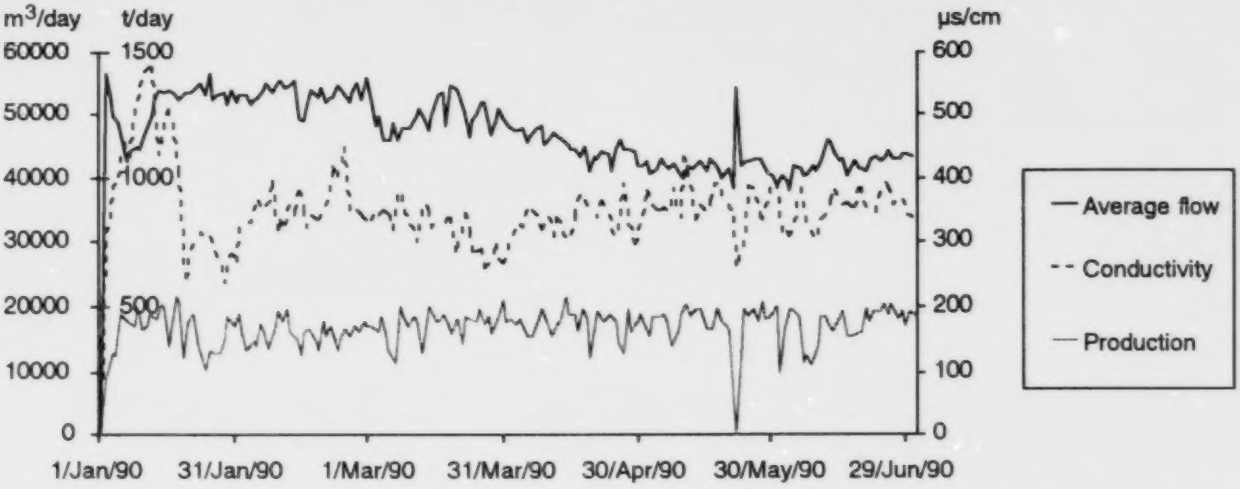
Table 8b. Metals (ATG 9 &12). Abitibi-Price Inc., Provincial Papers Division. (Date: 25-4-1991).

Company 00008601C	Prod. T/day	Daily flow m3/day	Berylium g/tonne	Aluminium g/tonne	Copper g/tonne	Zinc g/tonne	Chromium g/tonne	Nickel g/tonne	Molybdenum g/tonne	Cobalt g/tonne
Date										
Jan/90	417	44,292	-	265	0.7	4.2	-	-	-	-
Feb/90	340	55,079	-	347	-	5.1	-	-	-	-
Mar/90	433	49,167	-	198	26.1	8.6	-	-	-	-
Apr/90	451	47,520	-	230	12.2	2.8	-	-	-	-
May/90	475	40,232	-	174	-	3.1	0.3	-	-	-
Jun/90	286	41,558	-	161	0.4	3.0	-	-	-	-

Company 00008601C	Prod. T/day	Daily flow m3/day	Vanadium g/tonne	Silver g/tonne	Lead g/tonne	Cadmium g/tonne	Thallium g/tonne	Mercury g/tonne
Date								
Jan/90	417	44,292	1.5	-	0.1	0.04	-	-
Feb/90	340	55,079	1.1	-	0.3	0.06	-	-
Mar/90	433	49,167	-	0.5	0.2	0.05	-	-
Apr/90	451	47,520	2.1	-	0.3	0.01	-	-
May/90	475	40,232	-	-	1.7	-	-	-
Jun/90	286	41,558	1.6	-	-	-	-	-

Values for aluminium and zink are monthly averages.

Average flow, Production, and Conductivity data from Abitibi-Price Inc., Provincial Papers Division, Control point 0100 (9-5-1991).



DOC, TSS and BOD5 data from Abitibi-Price Inc., Provincial Papers Division, Control point 0100 (9-5-1991).

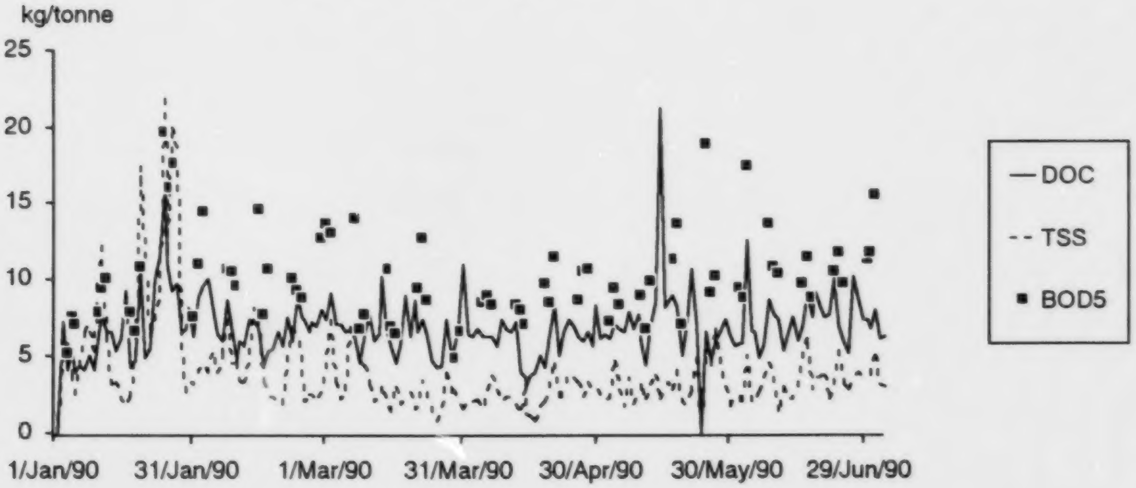


Table 1b. Halogenated volatiles (ATG16). Abitibi-Price Inc. , Iroquois Falls Division.. (Date: 18-5-1991).

Company: 0000860403

Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	Chloro-methane mg/tonne	Chloro-ethylene mg/tonne	Bromo-methane mg/tonne	Bromodi-chloromethane mg/tonne	Dichloro-methane mg/tonne	1,1-Dichloro-ethane mg/tonne	1,2-Dichloro-ethane mg/tonne	1,1-Dichloro-ethylene mg/tonne
Jan/90	929	62,700	-	-	142	-	297	-	-	-
Feb/90	842	58,809	-	-	-	-	196	-	-	-
Mar/90	830	60,559	2,701	-	-	-	-	-	-	-
Apr/90	900	59,830	5,847	49	505	26	638	13	54	21
May/90	873	64,360	-	-	-	-	-	-	-	-
Jun/90	822	67,460	-	-	-	-	-	-	-	-

Company: 0000860403

Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	trans-1,2-Di-chloroethylene mg/tonne	1,2-Dichloro-propane mg/tonne	cis-1,3-Di-chloropropylene mg/tonne	trans-1,3-Di-chloropropylene mg/tonne	Dibromo-ethylene mg/tonne	Trichloro-methane mg/tonne	Dibromo-chloromethane mg/tonne	Tribromo-methane mg/tonne	1,1,2-Tri-chloroethane mg/tonne
Jan/90	929	62,700	-	-	-	-	-	1,168	-	-	-
Feb/90	842	58,809	-	-	-	-	-	741	-	-	-
Mar/90	830	60,559	-	-	-	-	-	723	-	-	-
Apr/90	900	59,830	13	13	18	7	12	4,518	16	33	14
May/90	873	64,360	-	-	-	-	-	1,232	-	-	-
Jun/90	822	67,460	-	-	-	-	-	1,888	-	-	-

Company: 0000860403

Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	Trichloro-ethylene mg/tonne	Trifluoro-chloromethane mg/tonne	Tetrachloro-methane mg/tonne	1,1,2,2-Tetra-chloroethane mg/tonne	Tetrachloro-ethylene mg/tonne	Chloro-benzene mg/tonne	1,2-Dichloro-benzene mg/tonne	1,3-Dichloro-benzene mg/tonne	1,4-Dichloro-benzene mg/tonne
Jan/90	929	62,700	-	-	-	-	-	-	-	-	-
Feb/90	842	58,809	-	-	-	-	-	-	-	-	-
Mar/90	830	60,559	-	-	-	-	-	-	-	-	-
Apr/90	900	59,830	61	17	68	21	14	17	16	15	15
May/90	873	64,360	-	-	-	-	-	-	-	-	-
Jun/90	822	67,460	-	-	-	-	-	-	-	-	-

Table 2b. Nonhalogenated volatiles (ATG17). Abitibi-Price Inc. , Iroquois Falls Division.. (Date: 18-5-1991)

Company: 0000860403

Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Styrene mg/tonne	Benzene mg/tonne	m,p-Xylene mg/tonne	o-Xylene mg/tonne	Toluene mg/tonne
Jan/90	929	62,700	23	142	14	16	49
Feb/90	842	58,809	18	-	15	13	33
Mar/90	830	60,559	-	-	20	-	60
Apr/90	900	59,830	16	199	14	13	16
May/90	873	64,360	-	-	-	-	27
Jun/90	822	67,460	-	-	-	-	57

Table 9b. Inorganics (ATG 3, 4, 6, 7 & 15). Abitibi-Price Inc. , Iroquois Falls Division.. (Date: 18-5-1991)

Company: 0000860403

Cntr.pt.: 01 Date	Prod. T/day	Av. flow m3/day	pH	Conductivity µs/cm	NH3 + NH4 g/tonne	NO2+NO3 g/tonne	Total-N g/tonne	Total-P g/tonne	Sulphide g/tonne
Jan/90	833	62,187	5.1	1120	10	27	209	49	-
Feb/90	801	60,930	5.1	1129	6	17	221	38	-
Mar/90	770	56,932	5.2	1096	9	21	222	36	-
Apr/90	795	59,897	5.3	1174	11	5	226	35	-
May/90	817	64,782	4.9	1151	14	17	255	42	-
Jun/90	790	69,768	4.9	1129	14	21	327	44	-

Table 10b. Group and unspecific variables (ATG 1, 5, 8, PP1-3). Abitibi-Price Inc. , Iroquois Falls Division.. (Date: 18-5-1991).

Company: 0000860403

Cntr.pt.: 01 Date	Prod. T/day	Av. flow m3/tonne	BOD5 Kg/tonne	AOX Kg/tonne	COD Kg/tonne	DOC Kg/tonne	TOC Kg/tonne	TSS Kg/tonne	VSS Kg/tonne	DOC/BOD
Jan/90	833	75	70.2	-	-	60.3	-	9.7	-	0.9
Feb/90	801	76	73.0	-	-	64.1	-	9.1	-	0.9
Mar/90	770	74	65.5	-	-	55.9	-	8.0	-	0.9
Apr/90	795	75	70.9	-	-	56.8	-	10.1	-	0.8
May/90	817	79	66.3	-	-	64.0	-	10.2	-	1.0
Jun/90	790	88	73.4	-	-	68.3	-	10.1	-	0.9

Table 3b. Extractable base neutrals (ATG19). Abitibi-Price Inc. , Iroquois Falls Division.. (Date: 18-5-1991).

Company: 0000860403

Date	Cntr.pt.: 01 Prod. T/day	Daily flow m3/day	Naphthalene mg/tonne	1-Methyl-naphthalene mg/tonne	2-Methyl-naphthalene mg/tonne	1-Chloro-naphthalene mg/tonne	2-Chloro-naphthalene mg/tonne	Anthracene mg/tonne	Benz[a]-anthracene mg/tonne	Dibenz[a] anthracene mg/tonne
Jan/90	929	62,700	-	-	-	-	-	-	-	-
Feb/90	842	58,809	-	-	-	-	-	-	-	-
Mar/90	830	60,559	-	-	-	-	-	-	-	-
Apr/90	900	59,830	-	-	-	-	-	-	-	-
May/90	873	64,360	-	-	-	-	-	-	-	-
Jun/90	822	67,460	-	-	-	-	-	-	-	-

Company: 0000860403

Date	Cntr.pt.: 01 Prod. T/day	Daily flow m3/day	Phenan-threne mg/tonne	Acenaph-thene mg/tonne	Acenaph-thylene mg/tonne	5-Nitro-ace-naphthene mg/tonne	Chrysene mg/tonne	Fluor-anthene mg/tonne	Benz[b]-fluoranthene mg/tonne	Benz[k] fluoranthene mg/tonne	Fluorene mg/tonne
Jan/90	929	62,700	-	-	-	-	-	-	-	-	-
Feb/90	842	58,809	-	-	-	-	-	-	-	-	-
Mar/90	830	60,559	-	-	-	-	-	-	-	-	-
Apr/90	900	59,830	-	-	-	-	-	-	-	-	-
May/90	873	64,360	-	-	-	-	-	-	-	-	-
Jun/90	822	67,460	-	-	-	-	-	-	-	-	-

Company: 0000860403

Date	Cntr.pt.: 01 Prod. T/day	Daily flow m3/day	Pyrene mg/tonne	Benz[a]-pyrene mg/tonne	ideno[1,2,3-cd pyrene mg/tonne	Perylene mg/tonne	Benz[g,h,i]-perylene mg/tonne	Indole mg/tonne	Camphene mg/tonne
Jan/90	929	62,700	-	-	-	-	-	-	858
Feb/90	842	58,809	-	-	-	-	-	-	363
Mar/90	830	60,559	-	-	-	-	-	-	-
Apr/90	900	59,830	-	-	-	-	-	-	771
May/90	873	64,360	-	-	-	-	-	-	-
Jun/90	822	67,460	-	-	-	-	-	-	164

Table 4b. Acidic extractables (ATG20). Abitibi-Price Inc. , Iroquois Falls Division.. (Date: 18-5-1991).

Company: 0000860403

Date	Cntr.pt.: 01 Prod. T/day	Daily flow m3/day	Phenol mg/tonne	m-Cresol mg/tonne	o-Cresol mg/tonne	p-Cresol mg/tonne	2,4-xylenol mg/tonne	4-Chloro-m-cresol mg/tonne	2-Chloro-phenol mg/tonne	2,4-Dichloro-phenol mg/tonne
Jan/90	929	62,700	-	-	-	-	-	-	-	-
Feb/90	842	58,809	294	384	-	-	-	-	-	-
Mar/90	830	60,559	219	-	-	-	-	-	-	-
Apr/90	900	59,830	199	253	-	-	-	-	-	-
May/90	873	64,360	280	280	-	-	-	-	-	-
Jun/90	822	67,460	337	304	74	230	-	-	-	-

Company: 0000860403

Date	Cntr.pt.: 01 Prod. T/day	Daily flow m3/day	2,6-Dichloro-phenol mg/tonne	2,3,4-Tri-chlorophenol mg/tonne	2,3,5-Tri-chlorophenol mg/tonne	2,4,5-Tri-chlorophenol mg/tonne	2,4,6-Tri-chlorophenol mg/tonne	2,3,4,5-Tetra-chlorophenol mg/tonne	2,3,4,6-Tetra-chlorophenol mg/tonne	2,3,5,6-Tetra-chlorophenol mg/tonne	Penta-chlorophenol mg/tonne
Jan/90	929	62,700	-	-	-	-	-	-	-	-	-
Feb/90	842	58,809	-	-	-	-	-	-	-	-	-
Mar/90	830	60,559	-	-	-	-	-	-	-	-	-
Apr/90	900	59,830	-	-	-	-	-	-	-	-	-
May/90	873	64,360	-	-	-	-	-	-	-	-	-
Jun/90	822	67,460	-	-	-	-	-	-	-	-	-

Company: 0000860403

Date	Cntr.pt.: 01 Prod. T/day	Daily flow m3/day	4-Nitro-phenol mg/tonne	2,4-Dinitro-phenol mg/tonne	4,6-Dinitro-o-cresol mg/tonne
Jan/90	929	62,700	-	-	-
Feb/90	842	58,809	-	-	-
Mar/90	830	60,559	-	-	-
Apr/90	900	59,830	2,392	-	-
May/90	873	64,360	-	-	-
Jun/90	822	67,460	-	-	-

Table 5b. Chlorinated, neutrals (ATG(23). Abitibi-Price Inc. , Iroquois Falls Division.. (Date: 18-5-1991).

Company: 0000860403 Cntr.pt.: 01 Prod.	T/day	Daily flow m3/day	Hexachloro-ethane mg/tonne	Hexachloro-butadiene mg/tonne	Hexachloro-cyclopentadien mg/tonne	1,2,3-Trichloro-benzene mg/tonne	1,2,4-Trichloro-benzene mg/tonne	2,4,5-Trichloro-toluene mg/tonne	1,2,3,4-Tetra-chlorobenzene mg/tonne	1,2,3,5-Tetra-chlorobenzene mg/tonne
Date										
Jan/90	929	62,700	-	-	-	-	0.3	-	-	-
Feb/90	842	58,809	-	-	-	-	-	-	-	-
Mar/90	830	60,559	-	-	1.3	-	-	-	-	-
Apr/90	900	59,830	-	-	1.3	-	-	-	-	-
May/90	873	64,360	-	-	0.5	-	-	-	-	-
Jun/90	822	67,460	-	-	0.4	-	-	-	-	-

Company: 0000860403 Cntr.pt.: 01 Prod.	T/day	Daily flow m3/day	1,2,4,5-Tetra-chlorobenzene mg/tonne	Penta-chlorobenzene mg/tonne	Hexa-chlorobenzene mg/tonne	Octachloro-styrene mg/tonne
Date						
Jan/90	929	62,700	-	-	0.3	-
Feb/90	842	58,809	-	-	-	-
Mar/90	830	60,559	-	-	-	-
Apr/90	900	59,830	-	-	1.1	-
May/90	873	64,360	-	-	-	-
Jun/90	822	67,460	-	-	0.4	-

Table 6b. Chlorinated dioxins, dibenzofuranes and PCB's (ATG(23). Abitibi-Price Inc. , Iroquois Falls Division.. (Date: 18-5-1991).

Company: 0000860403 Cntr.pt.: 01 Prod.	T/day	Daily flow m3/day	2,3,7,8-TCDD µgtonne	Total TCDD µgtonne	Total TCDF µgtonne	Total PCDD µgtonne	Total PCDF µgtonne	Total HxCDD µgtonne	Total HxCDF µgtonne	Total HpCDD µgtonne
Date										
May/90	817	64,360	-	-	-	-	-	-	-	-
	-		-	-	-	-	-	-	-	-
	-		-	-	-	-	-	-	-	-
	-		-	-	-	-	-	-	-	-
	-		-	-	-	-	-	-	-	-
	-		-	-	-	-	-	-	-	-

Company: 0000860403 Cntr.pt.: 01 Prod.	T/day	Daily flow m3/day	Total HpCDF µg/tonne	OCDD µg/tonne	OCDF µg/tonne	Total PCB's µg/tonne
Date						
May/90	817	64,360	-	18.4	3.9	-
	-		-	-	-	-
	-		-	-	-	-
	-		-	-	-	-
	-		-	-	-	-
	-		-	-	-	-

Table 7b. Fatty and resin acids (ATG 26). Abitibi-Price Inc. , Iroquois Falls Division.. (Date: 18-5-1991).

Company: 0000860403 Cntr.pt.: 01 Prod.	T/day	Daily flow m3/day	Oleic acid g/tonne	Pimaric acid g/tonne	Abietic acid g/tonne	Dehydro-abietic acid g/tonne	Isopimaric acid g/tonne	Levopimaric acid g/tonne	Neoabietic acid g/tonne	Chlorodehydro-abietic acid g/tonne
Date										
Jan/90	929	62,700	-	4.8	297.1	266.3	276.8	-	29.7	-
Feb/90	842	58,809	4.3	50.3	202.7	334.9	188.7	17.5	18.2	-
Mar/90	830	60,559	-	-	153.3	214.5	-	1.0	9.3	-
Apr/90	900	59,830	4.5	21.9	179.4	273.7	206.0	17.9	16.6	3.3
May/90	873	64,360	7.1	21.4	236.0	328.4	69.3	56.1	62.0	-
Jun/90	822	67,460	17.2	50.1	270.9	296.4	287.3	36.1	40.2	-

Company: 0000860403 Cntr.pt.: 01 Prod.	T/day	Daily flow m3/day	Dichlorodehydro-abietic acid g/tonne	Total resin acids g/tonne	Total resin acids Kg/day	Total resin acids <mg/l>
Date						
Jan/90	929	62,700	-	874.7	812	12.96
Feb/90	842	58,809	-	812.2	683	11.62
Mar/90	830	60,559	-	378.1	314	5.18
Apr/90	900	59,830	-	718.9	647	10.82
May/90	873	64,360	-	773.2	675	10.48
Jun/90	822	67,460	-	980.9	806	11.95

Values for dehydroabietic acid and dichlorodehydroabietic acid are monthly averages

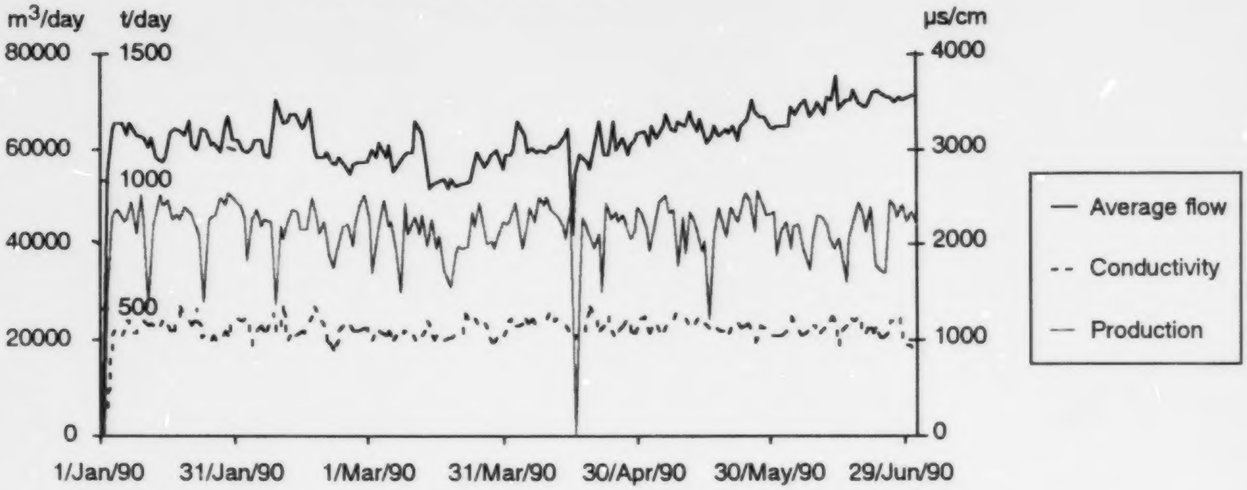
Table 6b. Metals (ATG 9 &12). Abitibi-Price Inc. , Iroquois Falls Division.. (Date: 18-5-1991).

Company 00008604C	Prod T/day	Daily flow m3/day	Berylium g/tonne	Aluminium g/tonne	Copper g/tonne	Zink g/tonne	Chromium g/tonne	Nickel g/tonne	Molybdenum g/tonne	Cobalt g/tonne
Date										
Jan/90	929	62,700	-	316	1.8	7.9	0.9	0.6	-	-
Feb/90	842	58,809	-	275	1.3	12.9	-	-	-	-
Mar/90	830	60,559	-	223	1.5	12.9	0.8	0.9	-	-
Apr/90	900	59,830	-	216	7.5	5.1	-	-	-	-
May/90	873	64,360	-	160	2.4	16.5	1.0	1.9	-	-
Jun/90	822	67,460	-	129	1.4	12.0	-	0.8	-	-

Company 00008604C	Prod T/day	Daily flow m3/day	Vanadium g/tonne	Silver g/tonne	Lead g/tonne	Cadmium g/tonne	Thallium g/tonne	Mercury g/tonne
Date								
Jan/90	929	62,700	0.8	-	0.5	0.06	-	-
Feb/90	842	58,809	0.8	-	-	0.06	-	-
Mar/90	830	60,559	0.5	-	0.2	0.07	-	0.03
Apr/90	900	59,830	-	-	0.5	0.01	-	0.00
May/90	873	64,360	2.1	-	5.2	-	-	-
Jun/90	822	67,460	-	-	-	-	2.46	-

Values for aluminium and zink are monthly averages

Average flow , Production and Conductivity data from Abitibi-Price Inc., Iroquois Falls Division. , Control point 0100 (5-5-1991).



TSS, DOC and BOD5 data from Abitibi-Price Inc. , Iroquois Falls Division., Control point 0100 (5-5-1991).

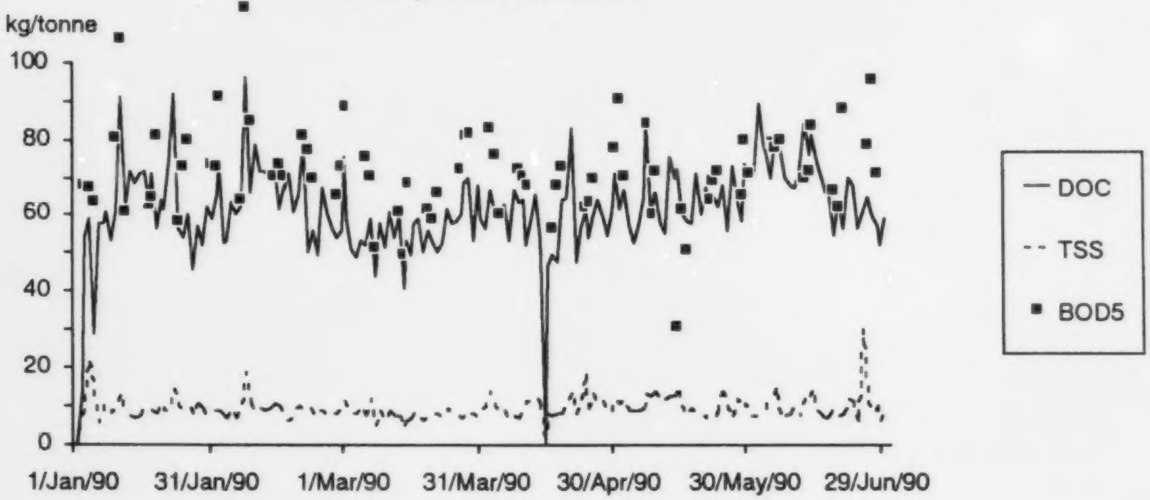


Table 1b. Halogenated volatiles (ATG16). Boise Cascade Canada Inc. (Kenora). (Date: 29-4-1991).

Company: 0000870006 Cntr pt.: 01	Prod T/day	Daily flow m3/day	Chloro- methane mg/tonne	Chloro- ethylene mg/tonne	Bromo- methane mg/tonne	Bromodi- chloromethane mg/tonne	Dichloro- methane mg/tonne	1,1-Dichloro- ethane mg/tonne	1,2-Dichloro- ethane mg/tonne	1,1-Dichloro- ethylene mg/tonne
Jan/90	1,005	45,540	-	-	-	-	-	-	-	-
Feb/90	981	46,860	-	-	-	-	-	-	-	-
Mar/90	1,041	40,540	-	-	-	-	-	-	-	-
Apr/90	1,084	43,305	-	-	-	-	-	-	-	-
May/90	892	52,500	-	-	-	-	-	-	-	-
Jun/90	855	45,990	-	-	-	355	-	-	-	-

Company: 0000870006 Cntr pt.: 01	Prod T/day	Daily flow m3/day	trans-1,2-Di- chloroethylene mg/tonne	1,2-Dichloro- propane mg/tonne	cis-1,3-Di- chloropropylen mg/tonne	trans-1,3-Di- chloropropylen mg/tonne	Dibromo- ethylene mg/tonne	Trichloro- methane mg/tonne	Dibromo- chloromethane mg/tonne	Tribromo- methane mg/tonne	1,1,2-Tri- chloroethane mg/tonne
Jan/90	1,005	45,540	-	-	-	-	-	372	-	-	-
Feb/90	981	46,860	-	-	-	-	-	306	-	-	-
Mar/90	1,041	40,540	-	-	-	-	-	-	-	-	-
Apr/90	1,084	43,305	-	-	-	-	-	108	-	-	-
May/90	892	52,500	-	-	-	-	-	647	-	-	0
Jun/90	855	45,990	-	-	-	-	-	602	-	-	-

Company: 0000870006 Cntr pt.: 01	Prod T/day	Daily flow m3/day	Trichloro- ethylene mg/tonne	Trifluoro- chloromethane mg/tonne	Tetrachloro- methane mg/tonne	1,1,2,2-Tetra- chloroethane mg/tonne	Tetrachloro- ethylene mg/tonne	Chloro- benzene mg/tonne	1,2-Dichloro- benzene mg/tonne	1,3-Dichloro- benzene mg/tonne	1,4-Dichloro- benzene mg/tonne
Jan/90	1,005	45,540	-	-	-	-	-	-	-	-	-
Feb/90	981	46,860	-	-	-	-	-	-	-	-	-
Mar/90	1,041	40,540	-	-	-	-	-	-	-	-	-
Apr/90	1,084	43,305	-	-	-	-	-	-	-	-	-
May/90	892	52,500	-	-	-	-	-	-	-	-	-
Jun/90	855	45,990	-	-	-	-	-	-	-	-	-

Table 2b. Nonhalogenated volatiles (ATG17). Boise Cascade Canada Inc. (Kenora). (Date: 29-4-1991).

Company: 0000870006 Cntr pt: 01	Prod T/day	Daily flow m3/day	Styrene mg/tonne	Benzene mg/tonne	m,p-Xylene mg/tonne	o-Xylene mg/tonne	Toluene mg/tonne
Date							
Jan/90	1,005	45,540	36	-	-	-	-
Feb/90	981	46,860	-	-	-	-	-
Mar/90	1,041	40,540	-	-	47	-	-
Apr/90	1,084	43,305	-	-	-	-	-
May/90	892	52,500	-	-	-	-	-
Jun/90	855	45,990	-	-	108	-	-

Table 9b. Inorganics (ATG 3, 4, 6, 7 & 15). Boise Cascade Canada Inc. (Kenora). (Date: 29-4-1991).

Company: 0000870006 Cntr pt.: 01	Prod T/day	Av. flow m3/day	pH	Conductivity µs/cm	NH3 + NH4 g/tonne	NO2+NO3 g/tonne	Total-N g/tonne	Total-P g/tonne	Sulphide g/tonne
Date									
Jan/90	971	46,123	4.9	1	12	17	180	11	-
Feb/90	975	48,642	4.8	1	12	27	60	15	-
Mar/90	991	45,344	4.5	1	1	14	142	16	-
Apr/90	887	46,509	4.3	1	1	15	76	17	-
May/90	892	49,367	4.3	1	1	11	89	13	-
Jun/90	855	50,870	4.5	3	1	13	1023	20	-

Table 10b. Group and unspecific variables (ATG 1, 5, 8, PP1-3). Boise Cascade Canada Inc. (Kenora). (Date: 29-4-1991).

Company: 0000870006 Cntr.pt.: 01	Prod. T/day	Av. flow m3/tonne	BOD5 Kg/tonne	AOX Kg/tonne	COD Kg/tonne	DOC Kg/tonne	TOC Kg/tonne	TSS Kg/tonne	VSS Kg/tonne	COD/BOD
Date										
Jan/90	971	47	32.1	-	103.5	-	-	3.1	-	3.2
Feb/90	975	50	40.9	-	115.1	-	-	3.5	-	2.8
Mar/90	991	46	38.8	-	102.2	-	-	3.2	-	2.6
Apr/90	887	52	39.3	-	115.3	-	-	4.2	-	2.9
May/90	892	55	41.2	-	120.6	-	-	4.0	-	2.9
Jun/90	855	59	37.5	-	110.4	0.1	-	4.1	-	2.9

Table 3b. Extractable base neutrals (ATG19). Boise Cascade Canada Inc. (Kenora). (Date: 29-4-1991).

Company: 0000870006 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Naphthalene mg/tonne	1-Methyl-naphthalene mg/tonne	2-Methyl-naphthalene mg/tonne	1-Chloro-naphthalene mg/tonne	2-Chloro-naphthalene mg/tonne	Anthracene mg/tonne	Benz[a]-anthracene mg/tonne	Dibenz[a] anthracene mg/tonne
Jan/90	1,005	45,540	-	-	-	-	-	-	-	-
Feb/90	981	46,070	-	-	-	-	-	-	-	-
Mar/90	1,041	47,240	27	-	-	-	-	-	-	-
Apr/90	1,084	43,305	-	-	-	-	-	-	-	-
May/90	892	49,140	-	-	28	-	-	-	-	-
Jun/90	855	45,990	-	-	-	-	-	-	-	-

Company: 0000870006 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Phenan-threne mg/tonne	Acenaph-thene mg/tonne	Acenaph-thylene mg/tonne	5-Nitro-ace-naphthene mg/tonne	Chrysene mg/tonne	Fluor-anthene mg/tonne	Benz[b]-fluoranthene mg/tonne	Benz[k] fluoranthene mg/tonne	Fluorene mg/tonne
Jan/90	1,005	45,540	-	-	-	-		-	-	-	-
Feb/90	981	46,070	-	-	-	-	-	-	-	-	-
Mar/90	1,041	47,240	-	-	-	-	-	-	-	-	-
Apr/90	1,084	43,305	-	-	-	-	-	-	-	-	-
May/90	892	49,140	55	-	-	-	-	-	-	-	14
Jun/90	855	45,990	38	-	-	-	-	-	-	-	-

Company: 0000870006 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Pyrene mg/tonne	Benz[a]-pyrene mg/tonne	ıdeno[1,2,3-cd pyrene mg/tonne	Perylene mg/tonne	Benz[g,h,i]-perylene mg/tonne	Indole mg/tonne	Camphene mg/tonne
Jan/90	1,005	45,540	-	-	-	-	-	-	-
Feb/90	981	46,070	-	-	-	-	-	-	329
Mar/90	1,041	47,240	-	-	-	-	-	-	163
Apr/90	1,084	43,305	-	-	-	-	-	-	120
May/90	892	49,140	-	-	-	-	-	-	1799
Jun/90	855	45,990	-	-	-	-	-	-	54

Table 4b. Acidic extractables (ATG20). Boise Cascade Canada Inc. (Kenora). (Date: 29-4-1991).

Company: 0000870006 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Phenol mg/tonne	m-Cresol mg/tonne	o-Cresol mg/tonne	p-Cresol mg/tonne	2,4-xylenol mg/tonne	4-Chloro-m-cresol mg/tonne	2-Chloro-phenol mg/tonne	2,4-Dichloro-phenol mg/tonne
Jan/90	1,005	45,540	-	-	-	-	-	-	-	-
Feb/90	981	46,070	94	14	-	-	23	-	-	80
Mar/90	1,041	47,240	64	236	-	-	-	-	-	-
Apr/90	1,084	43,305	44	-	-	-	-	-	-	-
May/90	892	49,140	52	-	36	-	-	-	-	-
Jun/90	855	45,990	-	-	-	-	1,140	-	-	-

Company: 0000870006 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	2,6-Dichloro-phenol mg/tonne	2,3,4-Tri-chlorophenol mg/tonne	2,3,5-Tri-chlorophenol mg/tonne	2,4,5-Tri-chlorophenol mg/tonne	2,4,6-Tri-chlorophenol mg/tonne	2,3,4,5-Tetra-chlorophenol mg/tonne	2,3,4,6-Tetra-chlorophenol mg/tonne	2,3,5,6-Tetra-chlorophenol mg/tonne	Penta-chlorophenol mg/tonne
Jan/90	1,005	45,540	-	-	-	-	-	-	-	-	-
Feb/90	981	46,070	-	-	-	-	-	-	-	-	-
Mar/90	1,041	47,240	-	-	-	-	-	-	-	-	-
Apr/90	1,084	43,305	-	-	-	-	-	-	-	-	-
May/90	892	49,140	-	-	-	-	-	-	-	-	0
Jun/90	855	45,990	-	-	-	-	-	-	-	-	-

Company: 0000870006 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	4-Nitro-phenol mg/tonne	2,4-Dinitro-phenol mg/tonne	4,6-Dinitro-o-cresol mg/tonne
Jan/90	1,005	45,540	-	-	-
Feb/90	981	46,070	-	-	-
Mar/90	1,041	47,240	-	-	-
Apr/90	1,084	43,305	-	-	-
May/90	892	49,140	-	-	-
Jun/90	855	45,990	-	-	-

Table 5b. Chlorinated, neutrals (ATG(23). Boise Cascade Canada Inc. (Kenora). (Date: 29-4-1991).

Company: 0000870006 Cntr.pt.: 01 Prod. Date	T/day	Daily flow m3/day	Hexachloro-ethane mg/tonne	Hexachloro-butadiene mg/tonne	Hexachloro-yclopentadien mg/tonne	1,2,3-Trichloro-benzene mg/tonne	1,2,4-Trichloro-benzene mg/tonne	2,4,5-Trichloro-toluene mg/tonne	1,2,3,4-Tetra-chlorobenzene mg/tonne	1,2,3,5-Tetra-chlorobenzene mg/tonne
Jan/90	1,005	45,540	1.6	-	-	2.2	7.1	10.4	0.9	-
Feb/90	981	46,070	-	1.2	2.3	2.6	3.9	32.9	0.9	-
Mar/90	1,041	47,240	-	-	-	5.9	-	-	-	-
Apr/90	1,084	43,305	-	-	-	5.3	-	-	-	-
May/90	892	49,140	-	-	-	1.3	-	-	-	-
Jun/90	855	45,990	-	-	-	-	-	29.9	-	-

Company: 0000870006 Cntr.pt.: 01 Prod. Date	T/day	Daily flow m3/day	1,2,4,5-Tetra-chlorobenzene mg/tonne	Penta-chlorobenzene mg/tonne	Hexa-chlorobenzene mg/tonne	Octachloro-styrene mg/tonne
Jan/90	1,005	45,540	-	0.9	1.4	-
Feb/90	981	46,070	-	2.0	1.0	-
Mar/90	1,041	47,240	-	-	-	-
Apr/90	1,084	43,305	-	1.2	-	0.5
May/90	892	49,140	-	-	-	-
Jun/90	855	45,990	-	-	-	-

Table 6b. Chlorinated dioxins, dibenzofuranes and PCB's (ATG(23). Boise Cascade Canada Inc. (Kenora). (Date: 29-4-1991).

Company: 0000870006 Cntr.pt.: 01 Prod. Date	T/day	Daily flow m3/day	2,3,7,8-TCDD µgtonne	Total TCDD µgtonne	Total TCDF µgtonne	Total PCDD µgtonne	Total PCDF µgtonne	Total HxCDD µgtonne	Total HxCDF µgtonne	Total HpCDD µgtonne
Jan/90	1,005	45,540	-	-	-	-	-	-	-	-
Mar/90	1,109	49,550	-	-	-	-	-	-	-	-
May/90	892	52,500	-	-	12.4	-	-	-	-	-
	-		-	-	-	-	-	-	-	-
	-		-	-	-	-	-	-	-	-
	-		-	-	-	-	-	-	-	-

Company: 0000870006 Cntr.pt.: 01 Prod. Date	T/day	Daily flow m3/day	Total HpCDF µg/tonne	OCDD µg/tonne	OCDF µg/tonne	Total PCB's µg/tonne
Jan/90	1,005	45,540	-	19.9	3.6	-
Mar/90	1,109	49,550	-	2.8	-	-
May/90	892	52,500	-	15.9	-	-
	-		-	-	-	-
	-		-	-	-	-
	-		-	-	-	-

Table 7b. Fatty and resin acids (ATG 26). Boise Cascade Canada Inc. (Kenora). (Date: 29-4-1991).

Company: 0000870006 Cntr.pt.: 01 Prod. Date	T/day	Daily flow m3/day	Oleic acid g/tonne	Pimaric acid g/tonne	Abietic acid g/tonne	Dehydro-abietic acid g/tonne	Isopimaric acid g/tonne	Levopimaric acid g/tonne	Neoabietic acid g/tonne	Chlorodehydro-abietic acid g/tonne
Jan/90	1,005	45,540	1.8	1.0	0.5	3011.5	0.9	-	0.3	0.3
Feb/90	981	46,070	3.3	3.3	25.5	124.0	11.6	6.7	4.6	5.7
Mar/90	1,041	47,240	39.8	45.8	0.5	324.4	345.7	-	-	4.4
Apr/90	1,084	43,305	44.9	2.0	322.1	196.4	387.8	-	-	2.2
May/90	892	49,140	54.7	51.0	281.7	252.4	312.2	-	49.2	17.8
Jun/90	855	45,990	140.8	58.7	355.1	322.7	393.1	-	109.5	19.4

Company: 0000870006 Cntr.pt.: 01 Prod. Date	T/day	Daily flow m3/day	Dichlorodehydr abietic acid g/tonne	Total resin acids g/tonne	Total resin acids Kg/day	Total resin acids <mg/l>
Jan/90	1,005	45,540	-	3014.4	3029	66.52
Feb/90	981	46,070	-	181.4	178	3.86
Mar/90	1,041	47,240	-	720.8	750	15.88
Apr/90	1,084	43,305	-	910.5	987	22.79
May/90	892	49,140	-	964.3	860	17.50
Jun/90	855	45,990	-	1258.6	1076	23.40

Values for dehydroabietic acid and dichlorodehydroabietic acid are monthly averages

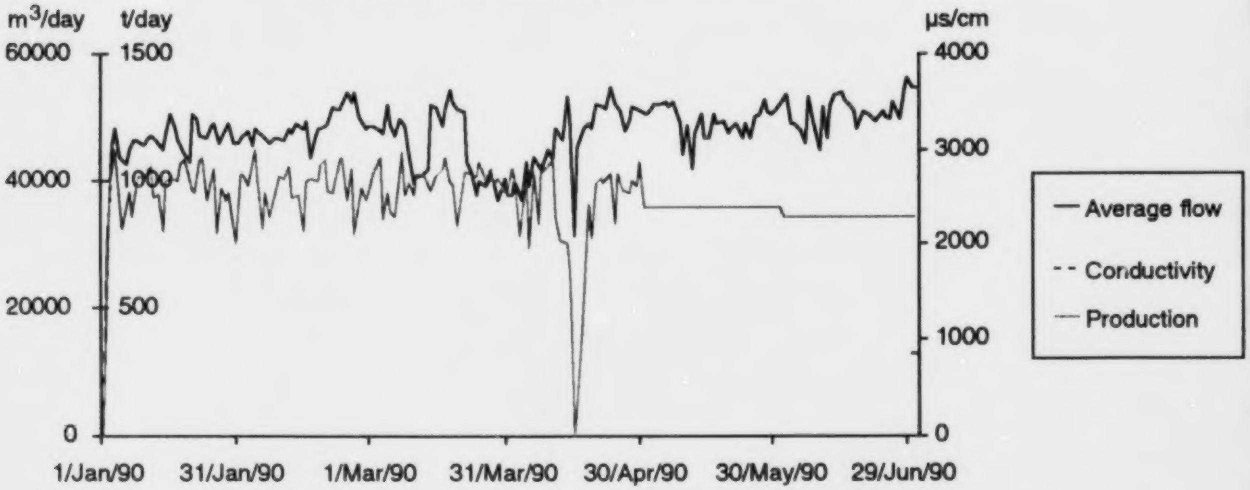
Table 8b. Metals (ATG 9 &12). Boise Cascade Canada Inc. (Kenora). (Date: 29-4-1991).

Company 00008700C Date	Prod. T/day	Daily flow m3/day	Berylium g/tonne	Aluminium g/tonne	Copper g/tonne	Zinc g/tonne	Chromium g/tonne	Nickel g/tonne	Molybdenum g/tonne	Cobalt g/tonne
Jan/90	1,005	45,540	-	12	0.9	3.0	-	-	-	-
Feb/90	981	46,070	-	12	0.8	3.7	-	-	-	-
Mar/90	1,041	47,240	-	11	0.8	3.1	3.8	-	-	-
Apr/90	1,084	43,305	0.09	8	0.7	2.7	0.2	-	-	-
May/90	892	49,140	0.10	12	0.9	2.7	0.2	-	0.2	-
Jun/90	855	45,990	0.12	24	1.3	3.3	0.2	0.4	0.1	-

Company 00008700C Date	Prod. T/day	Daily flow m3/day	Vanadium g/tonne	Silver g/tonne	Lead g/tonne	Cadmium g/tonne	Thallium g/tonne	Mercury g/tonne
Jan/90	1,005	45,540	-	-	-	-	-	-
Feb/90	981	46,070	-	-	-	-	-	-
Mar/90	1,041	47,240	0.1	-	-	-	-	-
Apr/90	1,084	43,305		-	-	-	-	-
May/90	892	49,140	-	-	-	-	1.10	-
Jun/90	855	45,990	0.1	-	0.5	-	0.81	-

Values for aluminium and zink are monthly averages

Average flow, Production, and Conductivity data from Boise Cascade Canada Inc. (Kenora), Control point 0100 (12-5-1991).



TSS, COD and BOD5 data from Boise Cascade Canada Inc. (Kenora), Control point 0100 (12-5-1991).

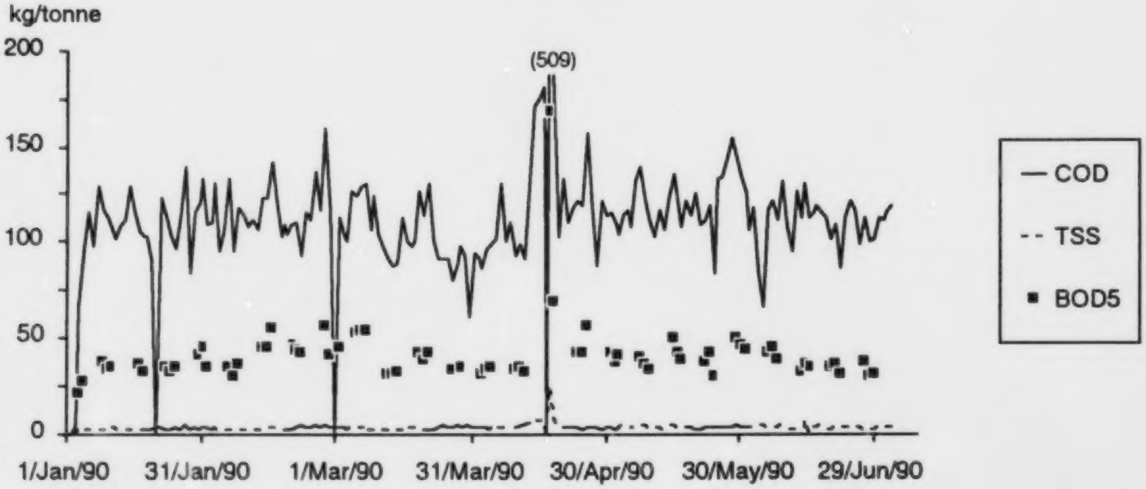


Table 1b. Halogenated volatiles (ATG16). Quebec & Ontario Paper Company Ltd.. (Date: 2-5-1991).

Company: 0000930008 Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	Chloro-methane mg/tonne	Chloro-ethylene mg/tonne	Bromo-methane mg/tonne	Bromodi-chloromethane mg/tonne	Dichloro-methane mg/tonne	1,1-Dichloro-ethane mg/tonne	1,2-Dichloro-ethane mg/tonne	1,1-Dichloro-ethylene mg/tonne
Jan/90	827	53,334	-	-	-	-	-	-	-	-
Feb/90	871	50,596	0	-	0	-	-	-	-	-
Mar/90	1,016	56,999	-	-	0	-	0	-	-	-
Apr/90	755	64,278	0	-	0	-	-	-	-	-
May/90	868	65,795	-	-	-	-	-	-	-	-
Jun/90	929	65,090	-	-	0	-	0	-	-	-

Company: 0000930008 Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	trans-1,2-Di-chloroethylene mg/tonne	1,2-Dichloro-propane mg/tonne	cis-1,3-Di-chloropropylene mg/tonne	trans-1,3-Di-chloropropylene mg/tonne	Dibromo-ethylene mg/tonne	Trichloro-methane mg/tonne	Dibromo-chloromethane mg/tonne	Tribromo-methane mg/tonne	1,1,2-Tri-chloroethane mg/tonne
Jan/90	827	53,334	-	-	-	-	-	0	-	-	-
Feb/90	871	50,596	-	-	-	-	-	0	-	-	-
Mar/90	1,016	56,999	-	-	-	-	-	0	-	-	-
Apr/90	755	64,278	-	-	-	-	-	0	-	-	-
May/90	868	65,795	-	-	-	-	-	-	-	-	0
Jun/90	929	65,090	-	-	-	-	-	-	-	-	-

Company: 0000930008 Cntr.pt.: 01	Prod T/day	Daily flow m3/day	Trichloro-ethylene mg/tonne	Trifluoro-chloromethane mg/tonne	Tetrachloro-methane mg/tonne	1,1,2,2-Tetra-chloroethane mg/tonne	Tetrachloro-ethylene mg/tonne	Chloro-benzene mg/tonne	1,2-Dichloro-benzene mg/tonne	1,3-Dichloro-benzene mg/tonne	1,4-Dichloro-benzene mg/tonne
Jan/90	827	53,334	-	-	-	-	-	-	-	-	-
Feb/90	871	50,596	-	-	-	-	-	-	-	-	-
Mar/90	1,016	56,999	-	-	-	-	-	-	-	-	-
Apr/90	755	64,278	-	-	-	-	-	-	-	-	-
May/90	868	65,795	-	-	-	-	-	-	-	-	-
Jun/90	929	65,090	-	-	-	-	-	-	-	-	-

Table 2b. Nonhalogenated volatiles (ATG17). Quebec & Ontario Paper Company Ltd.. (Date: 2-5-1991).

Company: 0000930008 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Styrene mg/tonne	Benzene mg/tonne	m,p-Xylene mg/tonne	o-Xylene mg/tonne	Toluene mg/tonne
Jan/90	827	53,334	-	-	-	-	0
Feb/90	871	50,596	-	-	-	-	-
Mar/90	1,016	56,999	-	0	-	0	0
Apr/90	755	64,278	-	0	-	-	0
May/90	868	65,795	-	-	-	-	0
Jun/90	929	65,090	-	-	-	-	-

Table 9b. Inorganics (ATG 3, 4, 6, 7 & 15). Quebec & Ontario Paper Company Ltd.. (Date: 2-5-1991).

Company: 0000930008 Cntr.pt.: 01 Date	Prod. T/day	Av. flow m3/day	pH	Conductivity µs/cm	NH3 + NH4 g/tonne	NO2+NO3 g/tonne	Total-N g/tonne	Total-P g/tonne	Sulphide g/tonne
Jan/90	845	50,667	7.3	685	68	9	171	10	-
Feb/90	841	55,164	7.1	671	56	11	213	24	-
Mar/90	929	56,642	7.3	648	47	10	171	12	-
Apr/90	742	62,893	7.3	605	123	40	247	40	-
May/90	868	65,795	7.4	825	61	23	197	40	-
Jun/90	828	65,113	7.3	798	113	21	294	46	-

Table 10b. Group and unspecific variables (ATG 1, 5, 8, PP1-3). Quebec & Ontario Paper Company Ltd.. (Date: 2-5-1991).

Company: 0000930008 Cntr.pt.: 01 Date	Prod. T/day	Av. flow m3/tonne	BOD5 Kg/tonne	AOX Kg/tonne	COD Kg/tonne	DOC Kg/tonne	TOC Kg/tonne	TSS Kg/tonne	VSS Kg/tonne	DOC/BOD
Jan/90	845	60	1.1	-	-	1.6	-	3.4	1.7	1.4
Feb/90	841	66	1.2	-	-	1.9	-	4.0	3.6	1.5
Mar/90	929	61	0.9	-	-	2.1	-	2.9	2.4	2.2
Apr/90	742	85	1.3	-	-	2.0	-	4.0	3.0	1.6
May/90	868	76	1.6	-	-	2.3	-	3.0	2.4	1.4
Jun/90	828	79	1.8	-	-	2.4	-	3.4	2.4	1.3

Table 3b. Extractable base neutrals (ATG19). Quebec & Ontario Paper Company Ltd.. (Date: 2-5-1991).

Company: 0000930008
Cntr.pt.: 01

Date	Prod. T/day	Daily flow m3/day	Naphthalene mg/tonne	1-Methyl-naphthalene mg/tonne	2-Methyl-naphthalene mg/tonne	1-Chloro-naphthalene mg/tonne	2-Chloro-naphthalene mg/tonne	Anthracene mg/tonne	Benz[a]-anthracene mg/tonne	Dibenz[a] anthracene mg/tonne
Jan/90	961	53,334	-	-	-	-	-	-	-	-
Feb/90	871	50,596	-	-	-	-	-	-	-	-
Mar/90	1,016	56,999	-	-	-	-	-	-	-	-
Apr/90	755	64,278	-	-	-	-	-	-	-	-
May/90	868	65,795	-	-	-	-	-	-	-	-
Jun/90	929	65,090	-	-	-	-	-	-	-	-

Company: 0000930008
Cntr.pt.: 01

Date	Prod. T/day	Daily flow m3/day	Phenan-threne mg/tonne	Acenaph-thene mg/tonne	Acenaph-thylene mg/tonne	5-Nitro-ace-naphthene mg/tonne	Chrysene mg/tonne	Fluor-anthene mg/tonne	Benz[b]-fluoranthene mg/tonne	Benz[k] fluoranthene mg/tonne	Fluorene mg/tonne
Jan/90	961	53,334	-	-	-	-	-	-	-	-	-
Feb/90	871	50,596	-	-	-	-	-	-	-	-	-
Mar/90	1,016	56,999	-	-	-	-	-	-	-	-	-
Apr/90	755	64,278	-	-	-	-	-	-	-	-	-
May/90	868	65,795	-	-	-	-	-	-	-	-	-
Jun/90	929	65,090	-	-	-	-	-	-	-	-	-

Company: 0000930008
Cntr.pt.: 01

Date	Prod. T/day	Daily flow m3/day	Pyrene mg/tonne	Benz[a]-pyrene mg/tonne	Ideno[1,2,3-cd pyrene mg/tonne	Perylene mg/tonne	Benz[g,h,i]-perylene mg/tonne	Indole mg/tonne	Camphene mg/tonne
Jan/90	961	53,334	-	-	-	-	-	-	-
Feb/90	871	50,596	-	-	-	-	-	-	-
Mar/90	1,016	56,999	-	-	-	-	-	-	-
Apr/90	755	64,278	-	-	-	-	-	-	-
May/90	868	65,795	-	-	-	-	-	0	-
Jun/90	929	65,090	-	-	-	-	-	-	-

Table 4b. Acidic extractables (ATG20). Quebec & Ontario Paper Company Ltd.. (Date: 2-5-1991).

Company: 0000930008
Cntr.pt.: 01

Date	Prod. T/day	Daily flow m3/day	Phenol mg/tonne	m-Cresol mg/tonne	o-Cresol mg/tonne	p-Cresol mg/tonne	2,4-xylenol mg/tonne	4-Chloro-m-cresol mg/tonne	2-Chloro-phenol mg/tonne	2,4-Dichloro-phenol mg/tonne
Jan/90	961	53,334	-	-	-	-	-	-	-	-
Feb/90	871	50,596	-	-	-	-	-	-	-	-
Mar/90	1,016	56,999	-	-	-	-	-	-	-	-
Apr/90	755	64,278	-	-	-	-	-	-	-	-
May/90	868	65,795	0	-	-	-	-	-	-	-
Jun/90	929	65,090	-	-	-	-	-	-	-	-

Company: 0000930008
Cntr.pt.: 01

Date	Prod. T/day	Daily flow m3/day	2,6-Dichloro-phenol mg/tonne	2,3,4-Tri-chlorophenol mg/tonne	2,3,5-Tri-chlorophenol mg/tonne	2,4,5-Tri-chlorophenol mg/tonne	2,4,6-Tri-chlorophenol mg/tonne	2,3,4,5-Tetra-chlorophenol mg/tonne	2,3,4,6-Tetra-chlorophenol mg/tonne	2,3,5,6-Tetra-chlorophenol mg/tonne	Penta-chlorophenol mg/tonne
Jan/90	961	53,334	-	-	-	-	-	-	-	-	-
Feb/90	871	50,596	-	-	-	-	-	-	-	-	-
Mar/90	1,016	56,999	-	-	-	-	-	-	-	-	-
Apr/90	755	64,278	-	-	-	-	-	-	-	-	-
May/90	868	65,795	-	-	-	-	-	-	-	-	0
Jun/90	929	65,090	-	-	-	-	-	-	-	-	-

Company: 0000930008
Cntr.pt.: 01

Date	Prod. T/day	Daily flow m3/day	4-Nitro-phenol mg/tonne	2,4-Dinitro-phenol mg/tonne	4,6-Dinitro-o-cresol mg/tonne
Jan/90	961	53,334	-	-	-
Feb/90	871	50,596	-	-	-
Mar/90	1,016	56,999	-	-	-
Apr/90	755	64,278	-	-	-
May/90	868	65,795	-	-	-
Jun/90	929	65,090	-	-	-

Table 5b. Chlorinated, neutrals (ATG(23). Quebec & Ontario Paper Company Ltd.. (Date: 2-5-1991).

Company: 0000930008 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Hexachloro-ethane mg/tonne	Hexachloro-butadiene mg/tonne	Hexachloro-cyclopentadien mg/tonne	1,2,3-Trichloro-benzene mg/tonne	1,2,4-Trichloro-benzene mg/tonne	2,4,5-Trichloro-toluene mg/tonne	1,2,3,4-Tetra-chlorobenzene mg/tonne	1,2,3,5-Tetra-chlorobenzene mg/tonne
Jan/90	961	53,334	-	-	0.0	-	-	0.0	0.0	-
Feb/90	871	50,596	-	-	-	-	0.0	-	-	-
Mar/90	1,016	56,999	-	-	-	-	-	0.0	-	-
Apr/90	755	64,278	-	-	-	-	-	-	-	-
May/90	868	65,795	-	-	-	-	0.0	-	0.0	-
Jun/90	929	65,090	-	-	-	-	0.0	-	-	-

Company: 0000930008 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	1,2,4,5-Tetra-chlorobenzene mg/tonne	Penta-chlorobenzene mg/tonne	Hexa-chlorobenzene mg/tonne	Octachloro-styrene mg/tonne
Jan/90	961	53,334	-	-	-	-
Feb/90	871	50,596	-	-	-	-
Mar/90	1,016	56,999	-	-	-	-
Apr/90	755	64,278	-	-	-	-
May/90	868	65,795	-	-	-	-
Jun/90	929	65,090	-	-	-	-

Table 6b. Chlorinated dioxins, dibenzofuranes and PCB's (ATG(23). Quebec & Ontario Paper Company Ltd.. (Date: 2-5-1991).

Company: 0000930008 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	2,3,7,8-TCDD µgtonne	Total TCDD µgtonne	Total TCDF µgtonne	Total PCDD µgtonne	Total PCDF µgtonne	Total HxCDD µgtonne	Total HxCDF µgtonne	Total HpCDD µgtonne
Mar/90	1,016	56,999	-	-	-	-	-	-	-	-

Company: 0000930008 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Total HpCDF µg/tonne	OCDD µg/tonne	OCDF µg/tonne	Total PCB's µg/tonne
Mar/90	1,016	56,999	-	-	-	-

Table 7b. Fatty and resin acids (ATG 26). Quebec & Ontario Paper Company Ltd.. (Date: 2-5-1991).

Company: 0000930008 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Oleic acid g/tonne	Pimaric acid g/tonne	Abietic acid g/tonne	Dehydro-abietic acid g/tonne	Isopimaric acid g/tonne	Levopimaric acid g/tonne	Neoabietic acid g/tonne	Chlorodehydro-abietic acid g/tonne
Jan/90	961	53,334	-	-	-	0.7	-	-	-	-
Feb/90	871	50,596	-	-	-	3.0	-	-	-	-
Mar/90	1,016	56,999	0.0	-	-	0.2	0.0	-	-	0.0
Apr/90	755	64,278	-	-	-	0.9	-	-	-	-
May/90	868	65,795	-	-	-	1.2	-	-	-	-
Jun/90	929	65,090	-	-	-	0.2	-	-	-	0.0

Company: 0000930008 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Dichlorodehydr abietic acid g/tonne	Total resin acids g/tonne	Total resin acids Kg/day	Total resin acids <mg/l>
Jan/90	961	53,334	-	0.7	1	0.01
Feb/90	871	50,596	-	3.0	3	0.05
Mar/90	1,016	56,999	-	0.2	0	0.00
Apr/90	755	64,278	-	0.9	1	0.01
May/90	868	65,795	-	1.2	1	0.02
Jun/90	929	65,090	-	0.2	0	0.00

Values for dehydroabietic acid and dichlorodehydroabietic acid are monthly averages

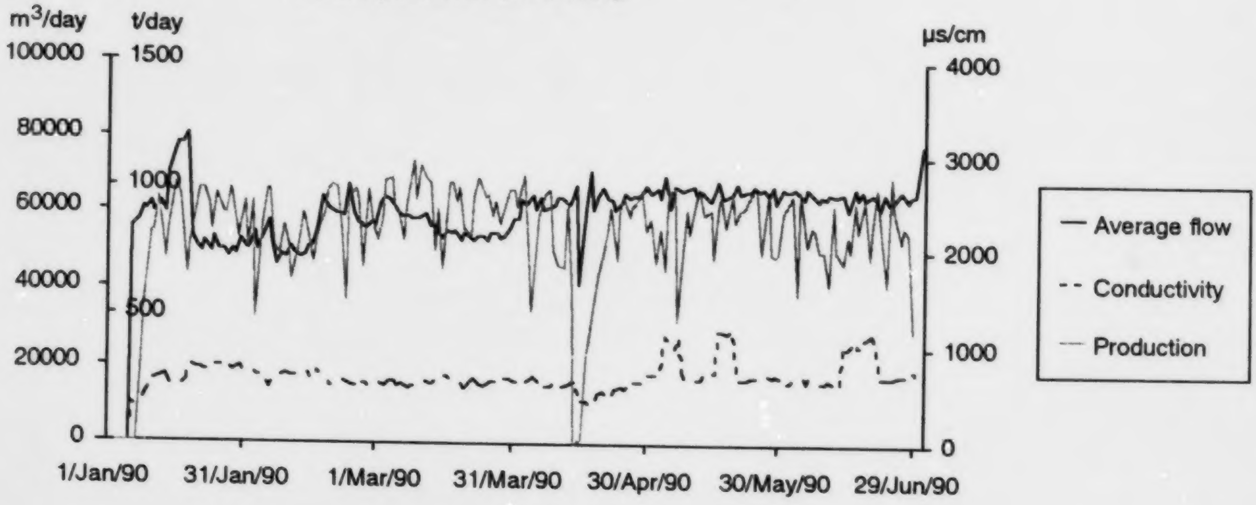
Table 8b. Metals (ATG 9 &12). Quebec & Ontario Paper Company Ltd.. (Date: 2-5-1991).

Company 00009300C Date	Prod. T/day	Daily flow m3/day	Berylium g/tonne	Aluminium g/tonne	Copper g/tonne	Zinc g/tonne	Chromium g/tonne	Nickel g/tonne	Molybdenum g/tonne	Cobalt g/tonne
Jan/90	961	53,334	-	24	0.0	10.4	0.0	0.0	-	-
Feb/90	871	50,596	-	26	0.0	13.0	0.0	0.0	0.0	-
Mar/90	1,016	56,999	-	13	0.0	9.8	0.0	0.0	-	-
Apr/90	755	64,278	-	264	0.0	14.8	-	-	-	-
May/90	868	65,795	-	26	0.0	8.8	0.0	0.0	-	-
Jun/90	929	65,090	-	20	0.0	14.9	-	-	-	-

Company 00009300C Date	Prod. T/day	Daily flow m3/day	Vanadium g/tonne	Silver g/tonne	Lead g/tonne	Cadmium g/tonne	Thallium g/tonne	Mercury g/tonne
Jan/90	961	53,334	0.0	-	0.0	0.00	-	-
Feb/90	871	50,596	0.0	-	0.0	0.00	-	-
Mar/90	1,016	56,999	0.0	-	0.0	0.00	-	-
Apr/90	755	64,278	0.0	-	-	-	-	0.00
May/90	868	65,795	0.0	-	-	-	-	-
Jun/90	929	65,090	-	-	-	-	-	-

Values for aluminium and zink are monthly averages.

Average flow, Production and Conductivity data from Quebec & Ontario Paper Company Ltd., Control point 0100 (17-5-1991).



TSS, DOC and BOD5 data from Quebec & Ontario Paper Company Ltd., Control point 0100 (17-5-1991).

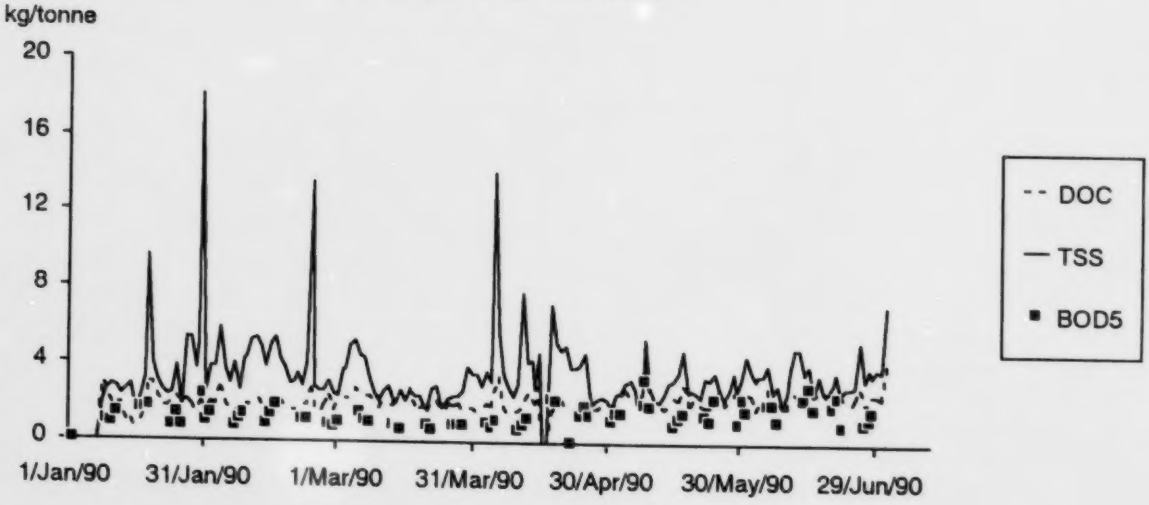


Table 1b. Halogenated volatiles (ATG16). St. Marys Paper Inc.. (Date: 2-5-1991).

Company: 0000860304 Cntr.pt.: 01 Prod	T/day	Daily flow m3/day	Chloro-methane mg/tonne	Chloro-ethylene mg/tonne	Bromo-methane mg/tonne	Bromodi-chloromethane mg/tonne	Dichloro-methane mg/tonne	1,1-Dichloro-ethane mg/tonne	1,2-Dichloro-ethane mg/tonne	1,1-Dichloro-ethylene mg/tonne
Jan/90	467	32,820	-	-	-	-	-	-	-	-
Feb/90	597	35,925	662	-	-	-	800	-	-	-
Mar/90	519	33,204	512	-	525	-	2,374	-	-	-
Apr/90	311	33,748	-	-	-	-	803	-	-	-
May/90	555	33,204	1,077	-	-	-	293	-	-	-
Jun/90	433	35,653	-	-	-	-	-	-	-	-

Company: 0000860304 Cntr.pt.: 01 Prod	T/day	Daily flow m3/day	trans-1,2-Di-chloroethylene mg/tonne	1,2-Dichloro-propane mg/tonne	cis-1,3-Di-chloropropylen mg/tonne	trans-1,3-Di-chloropropylen mg/tonne	Dibromo-ethylene mg/tonne	Trichloro-methane mg/tonne	Dibromo-chloromethane mg/tonne	Tribromo-methane mg/tonne	1,1,2-Tri-chloroethane mg/tonne
Jan/90	467	32,820	-	-	-	-	-	-	-	-	-
Feb/90	597	35,925	-	-	-	-	-	156	-	-	-
Mar/90	519	33,204	-	-	-	-	-	-	-	-	-
Apr/90	311	33,748	-	-	-	-	-	260	-	-	-
May/90	555	33,204	-	-	-	-	-	60	-	-	-
Jun/90	433	35,653	-	-	-	-	-	-	-	-	-

Company: 0000860304 Cntr.pt.: 01 Prod	T/day	Daily flow m3/day	Trichloro-ethylene mg/tonne	Trifluoro-chloromethane mg/tonne	Tetrachloro-methane mg/tonne	1,1,2,2-Tetra-chloroethane mg/tonne	Tetrachloro-ethylene mg/tonne	Chloro-benzene mg/tonne	1,2-Dichloro-benzene mg/tonne	1,3-Dichloro-benzene mg/tonne	1,4-Dichloro-benzene mg/tonne
Jan/90	467	32,820	-	-	-	-	-	-	-	-	-
Feb/90	597	35,925	-	-	-	-	-	-	-	-	-
Mar/90	519	33,204	-	-	-	-	-	-	-	-	-
Apr/90	311	33,748	-	-	-	-	-	-	-	-	-
May/90	555	33,204	-	-	-	-	-	-	-	-	-
Jun/90	433	35,653	-	-	-	-	-	-	-	-	-

Table 2b. Nonhalogenated volatiles (ATG17). St. Marys Paper Inc.. (Date: 2-5-1991).

Company: 0000860304 Cntr.pt.: 01 Prod Date	T/day	Daily flow m3/day	Styrene mg/tonne	Benzene mg/tonne	m,p-Xylene mg/tonne	o-Xylene mg/tonne	Toluene mg/tonne
Jan/90	467	32,820	-	-	-	-	107
Feb/90	597	35,925	-	-	-	-	138
Mar/90	519	33,204	-	192	112	20	47
Apr/90	311	33,748	-	-	56	22	93
May/90	555	33,204	-	72	-	-	221
Jun/90	433	35,653	-	86	-	-	165

Table 9b. Inorganics (ATG 3, 4, 6, 7 & 15). St. Marys Paper Inc.. (Date: 2-5-1991).

Company: 0000860304 Cntr.pt.: 01 Prod Date	T/day	Av. flow m3/day	pH	Conductivity µs/cm	NH3 + NH4 g/tonne	NO2+NO3 g/tonne	Total-N g/tonne	Total-P g/tonne	Sulphide g/tonne
Jan/90	465	32,513	6.4	173	5	3	66	80	-
Feb/90	520	32,936	6.7	293	7	5	124	37	-
Mar/90	532	33,436	6.8	294	4	4	64	40	-
Apr/90	487	34,419	6.9	247	7	8	59	51	-
May/90	552	32,387	6.8	280	4	3	50	32	-
Jun/90	480	34,360	6.7	284	5	3	59	75	-

Table 10b. Group and unspecific variables (ATG 1, 5, 8, PP1-3). St. Marys Paper Inc.. (Date: 2-5-1991).

Company: 0000860304 Cntr.pt.: 01 Prod. Date	T/day	Av. flow m3/tonne	BOD5 Kg/tonne	AOX Kg/tonne	COD Kg/tonne	DOC Kg/tonne	TOC Kg/tonne	TSS Kg/tonne	VSS Kg/tonne	COD/BOD
Jan/90	465	70	12.8	-	51.8	-	-	2.9	-	4.0
Feb/90	520	63	5.2	-	50.3	-	-	11.6	-	9.8
Mar/90	532	63	3.9	-	48.9	-	-	14.7	-	12.5
Apr/90	487	71	14.6	-	48.9	-	-	13.6	-	3.4
May/90	552	59	16.4	-	37.8	-	-	9.3	-	2.3
Jun/90	480	72	15.0	-	41.2	-	-	9.8	-	2.7

Table 3b. Extractable base neutrals (ATG19). St. Marys Paper Inc.. (Date: 2-5-1991).

Company: 0000860304
Cntr.pt.: 01

Date	Prod. T/day	Daily flow m3/day	Naphthalene mg/tonne	1-Methyl-naphthalene mg/tonne	2-Methyl-naphthalene mg/tonne	1-Chloro-naphthalene mg/tonne	2-Chloro-naphthalene mg/tonne	Anthracene mg/tonne	Benz[a]-anthracene mg/tonne	Dibenz[a] anthracene mg/tonne
Jan/90	467	32,820	-	-	-	-	-	-	-	-
Feb/90	597	35,925	156	-	-	-	-	-	-	-
Mar/90	519	33,204	128	-	-	-	-	-	-	-
Apr/90	311	33,748	434	-	-	-	-	-	-	-
May/90	555	33,204	66	-	-	-	-	-	-	-
Jun/90	433	35,653	82	-	-	-	-	-	-	-

Company: 0000860304
Cntr.pt.: 01

Date	Prod. T/day	Daily flow m3/day	Phenanthrene mg/tonne	Acenaphthene mg/tonne	Acenaphthylene mg/tonne	5-Nitro-acenaphthene mg/tonne	Chrysene mg/tonne	Fluoranthene mg/tonne	Benz[b]-fluoranthene mg/tonne	Benz[k] fluoranthene mg/tonne	Fluorene mg/tonne
Jan/90	467	32,820	-	-	-	-	-	-	-	-	-
Feb/90	597	35,925	-	-	-	-	-	-	-	-	-
Mar/90	519	33,204	-	-	-	-	-	-	-	-	-
Apr/90	311	33,748	-	-	-	-	-	54	-	-	-
May/90	555	33,204	-	-	-	-	-	-	-	-	-
Jun/90	433	35,653	-	-	-	-	-	-	-	-	-

Company: 0000860304
Cntr.pt.: 01

Date	Prod. T/day	Daily flow m3/day	Pyrene mg/tonne	Benz[a]-pyrene mg/tonne	ıdeno[1,2,3-cd pyrene mg/tonne	Perylene mg/tonne	Benz[g,h,i]-perylene mg/tonne	Indole mg/tonne	Camphene mg/tonne
Jan/90	467	32,820	-	-	-	-	-	-	-
Feb/90	597	35,925	-	-	-	-	-	-	-
Mar/90	519	33,204	-	-	-	-	-	-	-
Apr/90	311	33,748	43	-	-	-	-	-	-
May/90	555	33,204	-	-	-	-	-	-	18
Jun/90	433	35,653	-	-	-	-	-	-	33

Table 4b. Acidic extractables (ATG20). St. Marys Paper Inc.. (Date: 2-5-1991).

Company: 0000860304
Cntr.pt.: 01

Date	Prod. T/day	Daily flow m3/day	Phenol mg/tonne	m-Cresol mg/tonne	o-Cresol mg/tonne	p-Cresol mg/tonne	2,4-xylenol mg/tonne	4-Chloro-m-cresol mg/tonne	2-Chloro-phenol mg/tonne	2,4-Dichloro-phenol mg/tonne
Jan/90	467	32,820	408	-	-	387	-	-	-	-
Feb/90	597	35,925	-	-	-	-	-	-	-	-
Mar/90	519	33,204	-	-	-	429	-	-	-	-
Apr/90	311	33,748	48	-	-	-	-	-	-	-
May/90	555	33,204	138	126	-	371	-	-	-	-
Jun/90	433	35,653	576	313	33	2,306	-	-	-	41

Company: 0000860304
Cntr.pt.: 01

Date	Prod. T/day	Daily flow m3/day	2,6-Dichloro-phenol mg/tonne	2,3,4-Tri-chlorophenol mg/tonne	2,3,5-Tri-chlorophenol mg/tonne	2,4,5-Tri-chlorophenol mg/tonne	2,4,6-Tri-chlorophenol mg/tonne	2,3,4,5-Tetra-chlorophenol mg/tonne	2,3,4,6-Tetra-chlorophenol mg/tonne	2,3,5,6-Tetra-chlorophenol mg/tonne	Penta-chlorophenol mg/tonne
Jan/90	467	32,820	-	-	-	-	-	-	-	-	-
Feb/90	597	35,925	-	-	-	-	-	-	-	-	-
Mar/90	519	33,204	-	-	-	-	-	-	-	-	-
Apr/90	311	33,748	-	-	-	-	-	-	-	-	-
May/90	555	33,204	-	-	-	-	-	-	-	-	-
Jun/90	433	35,653	-	-	-	-	-	-	-	-	-

Company: 0000860304
Cntr.pt.: 01

Date	Prod. T/day	Daily flow m3/day	4-Nitro-phenol mg/tonne	2,4-Dinitro-phenol mg/tonne	4,6-Dinitro-o-cresol mg/tonne
Jan/90	467	32,820	-	-	-
Feb/90	597	35,925	-	-	-
Mar/90	519	33,204	-	-	-
Apr/90	311	33,748	-	-	-
May/90	555	33,204	-	-	-
Jun/90	433	35,653	494	-	-

Table 5b. Chlorinated, neutrals (ATG(23). St. Marys Paper Inc.. (Date: 2-5-1991).

Company: 0000860304 Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	Hexachloro-ethane mg/tonne	Hexachloro-butadiene mg/tonne	Hexachloro-yclopentadien mg/tonne	1,2,3-Trichloro-benzene mg/tonne	1,2,4-Trichloro-benzene mg/tonne	2,4,5-Trichloro-toluene mg/tonne	1,2,3,4-Tetra-chlorobenzene mg/tonne	1,2,3,5-Tetra-chlorobenzene mg/tonne
Date										
Jan/90	467	32,820	-	-	-	0.2	0.6	-	-	-
Feb/90	597	35,925	-	-	-	-	0.2	-	-	-
Mar/90	519	33,204	-	-	-	-	-	0.3	-	-
Apr/90	311	33,748	-	-	-	-	-	-	-	-
May/90	555	33,204	-	-	-	-	0.2	-	-	-
Jun/90	433	35,653	-	-	-	-	-	-	0.2	-

Company: 0000860304 Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	1,2,4,5-Tetra-chlorobenzene mg/tonne	Penta-chlorobenzene mg/tonne	Hexa-chlorobenzene mg/tonne	Octachloro-styrene mg/tonne
Date						
Jan/90	467	32,820	-	-	-	-
Feb/90	597	35,925	-	-	0.7	-
Mar/90	519	33,204	-	-	0.3	-
Apr/90	311	33,748	-	-	-	-
May/90	555	33,204	-	-	0.2	-
Jun/90	433	35,653	-	-	-	-

Table 6b. Chlorinated dioxins, dibenzofuranes and PCB's (ATG(23). St. Marys Paper Inc.. (Date: 2-5-1991).

Company: 0000860304 Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	2,3,7,8-TCDD µgtonne	Total TCDD µgtonne	Total TCDF µgtonne	Total PCDD µgtonne	Total PCDF µgtonne	Total HxCDD µgtonne	Total HxCDF µgtonne	Total HpCDD µgtonne
Date										
Feb/90	483	31,843	-	-	-	-	-	-	-	-
Apr/90	379	34,700	-	-	-	-	-	-	-	-
Jun/90	384	34,836	-	-	-	-	-	-	-	-

Company: 0000860304 Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	Total HpCDF µg/tonne	OCDD µg/tonne	OCDF µg/tonne	Total PCB's µg/tonne
Date						
Feb/90	483	31,843	-	28.3	-	-
Apr/90	379	34,700	-	-	-	-
Jun/90	384	34,836	-	12.7	-	-

Table 7b. Fatty and resin acids (ATG 26). St. Marys Paper Inc.. (Date: 2-5-1991).

Company: 0000860304 Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	Oleic acid g/tonne	Pimaric acid g/tonne	Abietic acid g/tonne	Dehydro-abietic acid g/tonne	Isopimaric acid g/tonne	Levopimaric acid g/tonne	Neoabietic acid g/tonne	Chlorodehydro-abietic acid g/tonne
Date										
Jan/90	467	32,820	2.1	24.6	45.7	124.7	118.8	13.9	10.9	-
Feb/90	597	31,843	1.2	18.7	80.0	132.7	59.2	45.9	37.9	-
Feb/90	519	35,925	6.0	18.0	101.1	113.0	76.1	54.7	47.8	-
Mar/90	311	33,204	-	43.8	104.6	262.9	-	33.1	37.4	-
Apr/90	555	33,748	-	6.7	31.6	112.5	23.1	-	-	1.6
May/90	433	33,204	1.2	6.4	40.6	178.5	32.2	16.1	13.6	-

Company: 0000860304 Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	Dichlorodehydr abietic acid g/tonne	Total resin acids g/tonne	Total resin acids Kg/day	Total resin acids <mg/l>
Date						
Jan/90	467	32,820	-	338.6	158	4.82
Feb/90	597	31,843	-	374.3	223	7.02
Feb/90	519	35,925	-	410.7	213	5.93
Mar/90	311	33,204	-	481.8	150	4.51
Apr/90	555	33,748	-	175.5	97	2.89
May/90	433	33,204	-	287.4	124	3.75

Values for dehydroabietic acid and dichlorodehydroabietic acid are monthly averages

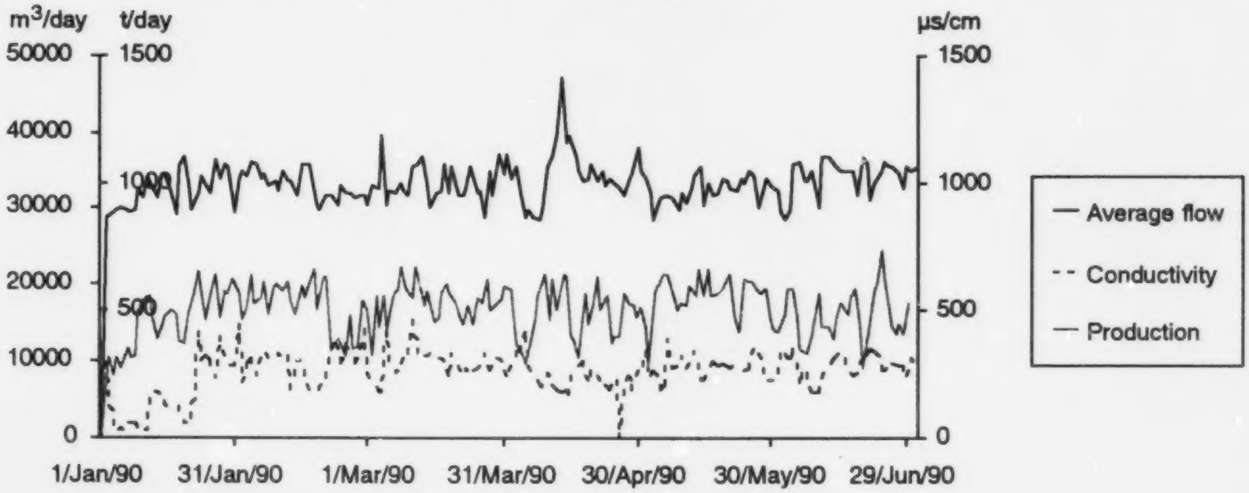
Table 8b. Metals (ATG 9 &12). St. Marys Paper Inc.. (Date: 2-5-1991).

Company 00008603C	Prod. T/day	Daily flow m3/day	Berylium g/tonne	Aluminium g/tonne	Copper g/tonne	Zinc g/tonne	Chromium g/tonne	Nickel g/tonne	Molybdenum g/tonne	Cobalt g/tonne
Date										
Jan/90	467	32,820	-	175	1.0	3.2	0.8	-	-	-
Feb/90	597	35,925	-	115	0.7	2.6	0.5	-	-	-
Mar/90	519	33,204	-	126	1.0	5.5	-	-	-	-
Apr/90	311	33,748	-	266	-	3.1	-	-	-	-
May/90	555	33,204	-	82	0.4	3.0	0.6	-	-	-
Jun/90	433	35,653	-	204	-	6.1	-	0.5	-	-

Company 00008603C	Prod. T/day	Daily flow m3/day	Vanadium g/tonne	Silver g/tonne	Lead g/tonne	Cadmium g/tonne	Thallium g/tonne	Mercury g/tonne
Date								
Jan/90	467	32,820	1.0	-	0.1	0.02	-	-
Feb/90	597	35,925	0.4	-	0.2	0.02	-	-
Mar/90	519	33,204	0.6	-	4.3	0.02	-	-
Apr/90	311	33,748	1.2	-	-	-	-	-
May/90	555	33,204	-	-	0.6	-	-	-
Jun/90	433	35,653	-	-	-	-	-	-

Values for aluminium and zink are monthly averages.

Average flow, Production and Conductivity data from St. Marys Paper Inc., Control point 0100 (17-5-1991).



TSS, COD and BOD5 data from St. Marys Paper Inc., Control point 0100 (17-5-1991).

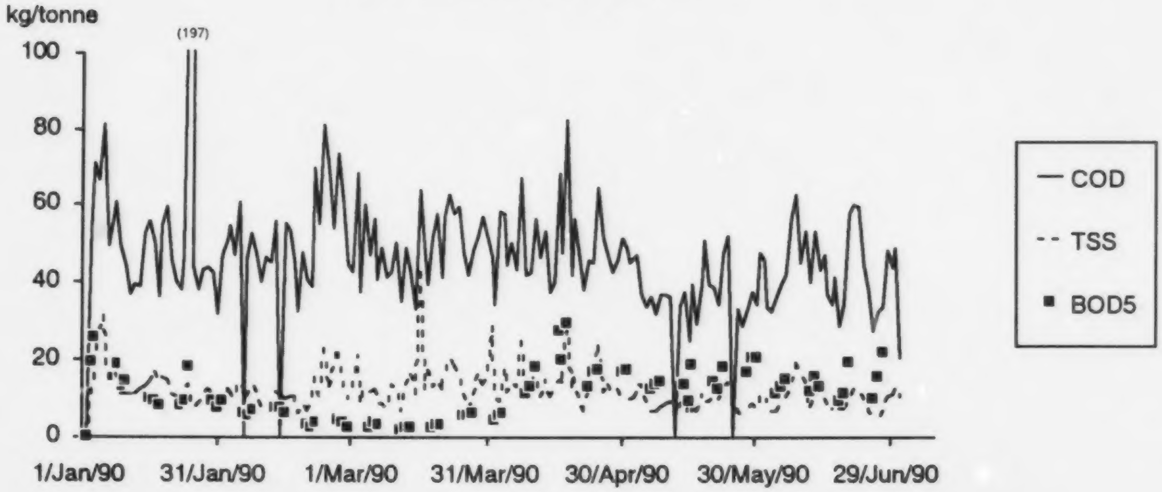


Table 1b. Halogenated volatiles (ATG16). Spruce Falls Power and Paper Company Ltd.. (Date: 2-5-1991).

Company: 0001340009

Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	Chloro-methane mg/tonne	Chloro-ethylene mg/tonne	Bromo-methane mg/tonne	Bromodi-chloromethane mg/tonne	Dichloro-methane mg/tonne	1,1-Dichloro-ethane mg/tonne	1,2-Dichloro-ethane mg/tonne	1,1-Dichloro-ethylene mg/tonne
Jan/90	1,115	75,556	-	-	-	-	-	-	-	-
Feb/90	1,087	78,323	-	-	-	-	-	-	-	-
Mar/90	1,071	84,330	-	-	-	-	-	-	-	-
Apr/90	1,077	84,152	-	-	-	-	-	-	-	-
May/90	1,039	82,384	-	-	-	-	-	-	-	-
Jun/90	1,028	91,483	-	-	-	-	-	-	-	-

Company: 0001340009

Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	trans-1,2-Di-chloroethylene mg/tonne	1,2-Dichloro-propane mg/tonne	cis-1,3-Di-chloropropylene mg/tonne	trans-1,3-Di-chloropropylene mg/tonne	Dibromo-ethylene mg/tonne	Trichloro-methane mg/tonne	Dibromo-chloromethane mg/tonne	Tribromo-methane mg/tonne	1,1,2-Tri-chloroethane mg/tonne
Jan/90	1,115	75,556	-	-	-	-	-	-	-	-	-
Feb/90	1,087	78,323	-	-	-	-	-	440	-	-	-
Mar/90	1,071	84,330	-	-	-	-	-	291	-	-	-
Apr/90	1,077	84,152	-	-	-	-	-	367	-	-	-
May/90	1,039	82,384	-	-	-	-	-	-	-	-	0
Jun/90	1,028	91,483	-	-	-	-	-	516	-	-	-

Company: 0001340009

Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	Trichloro-ethylene mg/tonne	Trifluoro-chloromethane mg/tonne	Tetrachloro-methane mg/tonne	1,1,2,2-Tetra-chloroethane mg/tonne	Tetrachloro-ethylene mg/tonne	Chloro-benzene mg/tonne	1,2-Dichloro-benzene mg/tonne	1,3-Dichloro-benzene mg/tonne	1,4-Dichloro-benzene mg/tonne
Jan/90	1,115	75,556	-	-	-	-	-	-	-	-	-
Feb/90	1,087	78,323	-	-	-	-	-	-	-	-	-
Mar/90	1,071	84,330	-	-	-	-	-	-	-	-	-
Apr/90	1,077	84,152	-	-	-	-	-	-	-	-	-
May/90	1,039	82,384	-	-	-	-	-	-	-	-	-
Jun/90	1,028	91,483	-	-	-	-	-	-	-	-	-

Table 2b. Nonhalogenated volatiles (ATG17). Spruce Falls Power and Paper Company Ltd.. (Date: 2-5-1991).

Company: 0001340009

Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Styrene mg/tonne	Benzene mg/tonne	m,p-Xylene mg/tonne	o-Xylene mg/tonne	Toluene mg/tonne
Jan/90	1,115	75,556	-	-	-	-	156
Feb/90	1,087	78,323	-	-	-	-	-
Mar/90	1,071	84,330	-	-	-	-	307
Apr/90	1,077	84,152	-	-	-	-	359
May/90	1,039	82,384	-	-	-	-	381
Jun/90	1,028	91,483	-	-	-	-	-

Table 9b. Inorganics (ATG 3, 4, 6, 7 & 15). Spruce Falls Power and Paper Company Ltd.. (Date: 2-5-1991).

Company: 0001340009

Cntr.pt.: 01 Date	Prod. T/day	Av. flow m3/day	pH	Conductivity µs/cm	NH3 + NH4 g/tonne	NO2+NO3 g/tonne	Total-N g/tonne	Total-P g/tonne	Sulphide g/tonne
Jan/90	934	74,932	6.0	307	8	6	122	36	-
Feb/90	1,027	77,668	6.1		12	6	129	30	-
Mar/90	975	79,439	6.1		8	4	19	24	-
Apr/90	1,024	78,811	5.5		8	4	131	15	-
May/90	981	71,757	5.7		7	4	132	15	-
Jun/90	950	90,423	5.8		10	10	171	29	-

Table 10b. Group and unspecific variables (ATG 1, 5, 8, PP1-3). Spruce Falls Power and Paper Company Ltd.. (Date: 2-5-1991).

Company: 0001340009

Cntr.pt.: 01 Date	Prod. T/day	Av. flow m3/tonne	BOD5 Kg/tonne	AOX Kg/tonne	COD Kg/tonne	DOC Kg/tonne	TOC Kg/tonne	TSS Kg/tonne	VSS Kg/tonne	COD/BOD
Jan/90	934	80	31.8	-	99.4	-	-	9.2	-	3.1
Feb/90	1,027	76	31.1	-	102.6	-	-	7.8	-	3.3
Mar/90	975	81	33.4	-	70.6	-	-	6.8	-	2.1
Apr/90	1,024	77	31.4	-	52.2	-	-	7.2	-	1.7
May/90	981	73	30.7	-	48.6	-	-	8.3	-	1.6
Jun/90	950	95	35.6	-	59.3	-	-	8.5	-	1.7

Table 3b. Extractable base neutrals (ATG19). Spruce Falls Power and Paper Company Ltd.. (Date: 2-5-1991).

Company: 0001340009 Cntr.pt.: 01 Date	Prod T/day	Daily flow m3/day	Naphthalene mg/tonne	1-Methyl-naphthalene mg/tonne	2-Methyl-naphthalene mg/tonne	1-Chloro-naphthalene mg/tonne	2-Chloro-naphthalene mg/tonne	Anthracene mg/tonne	Benz[a]-anthracene mg/tonne	Dibenz[a] anthracene mg/tonne
Jan/90	1,115	75,556	-	-	-	-	-	-	-	-
Feb/90	1,087	78,323	-	-	-	-	-	-	-	-
Mar/90	1,071	84,330	-	-	-	-	-	-	-	-
Apr/90	1,077	84,152	-	-	-	-	-	-	-	-
May/90	1,039	82,384	-	-	-	-	-	-	-	-
Jun/90	1,028	91,483	-	-	-	-	-	-	-	-

Company: 0001340009 Cntr.pt.: 01 Date	Prod T/day	Daily flow m3/day	Phenan-threne mg/tonne	Acenaph-thene mg/tonne	Acenaph-thylene mg/tonne	5-Nitro-ace-naphthene mg/tonne	Chrysene mg/tonne	Fluor-anthene mg/tonne	Benz[b]-fluoranthene mg/tonne	Benz[k] fluoranthene mg/tonne	Fluorene mg/tonne
Jan/90	1,115	75,556	-	-	-	-	-	-	-	-	-
Feb/90	1,087	78,323	-	-	-	-	-	-	-	-	-
Mar/90	1,071	84,330	-	-	-	-	-	-	-	-	-
Apr/90	1,077	84,152	-	-	-	-	-	-	-	-	-
May/90	1,039	82,384	-	-	-	-	-	-	-	-	-
Jun/90	1,028	91,483	-	-	-	-	-	-	-	-	-

Company: 0001340009 Cntr.pt.: 01 Date	Prod T/day	Daily flow m3/day	Pyrene mg/tonne	Benz[a]-pyrene mg/tonne	ıdeno[1,2,3-cd pyrene mg/tonne	Perylene mg/tonne	Benz[g,h,i]-perylene mg/tonne	Indole mg/tonne	Camphene mg/tonne
Jan/90	1,115	75,556	-	-	-	-	-	-	515
Feb/90	1,087	78,323	-	-	-	-	-	-	-
Mar/90	1,071	84,330	-	-	-	-	-	-	142
Apr/90	1,077	84,152	-	-	-	-	-	-	-
May/90	1,039	82,384	-	-	-	-	-	-	-
Jun/90	1,028	91,483	-	-	-	-	-	-	-

Table 4b. Acidic extractables (ATG20). Spruce Falls Power and Paper Company Ltd.. (Date: 2-5-1991).

Company: 0001340009 Cntr.pt.: 01 Date	Prod T/day	Daily flow m3/day	Phenol mg/tonne	m-Cresol mg/tonne	o-Cresol mg/tonne	p-Cresol mg/tonne	2,4-xylenol mg/tonne	4-Chloro-m-cresol mg/tonne	2-Chloro-phenol mg/tonne	2,4-Dichloro-phenol mg/tonne
Jan/90	1,115	75,556	-	-	-	-	-	-	-	-
Feb/90	1,087	78,323	187	-	-	-	-	-	-	-
Mar/90	1,071	84,330	-	-	-	-	-	-	-	-
Apr/90	1,077	84,152	102	-	-	-	-	-	-	-
May/90	1,039	82,384	151	-	-	-	-	-	-	-
Jun/90	1,028	91,483	-	-	-	-	-	-	-	-

Company: 0001340009 Cntr.pt.: 01 Date	Prod T/day	Daily flow m3/day	2,6-Dichloro-phenol mg/tonne	2,3,4-Tri-chlorophenol mg/tonne	2,3,5-Tri-chlorophenol mg/tonne	2,4,5-Tri-chlorophenol mg/tonne	2,4,6-Tri-chlorophenol mg/tonne	2,3,4,5-Tetra-chlorophenol mg/tonne	2,3,4,6-Tetra-chlorophenol mg/tonne	2,3,5,6-Tetra-chlorophenol mg/tonne	Penta-chlorophenol mg/tonne
Jan/90	1,115	75,556	-	-	-	-	-	-	-	-	-
Feb/90	1,087	78,323	-	-	-	-	-	-	-	-	-
Mar/90	1,071	84,330	-	-	-	-	-	-	-	-	-
Apr/90	1,077	84,152	-	-	-	-	-	-	-	-	-
May/90	1,039	82,384	-	-	-	-	-	-	-	-	0
Jun/90	1,028	91,483	-	-	-	-	-	-	-	-	-

Company: 0001340009 Cntr.pt.: 01 Date	Prod T/day	Daily flow m3/day	4-Nitro-phenol mg/tonne	2,4-Dinitro-phenol mg/tonne	4,6-Dinitro-o-cresol mg/tonne
Jan/90	1,115	75,556	-	-	-
Feb/90	1,087	78,323	-	-	-
Mar/90	1,071	84,330	-	-	-
Apr/90	1,077	84,152	-	-	-
May/90	1,039	82,384	-	-	-
Jun/90	1,028	91,483	-	-	-

Table 5b. Chlorinated, neutrals (ATG(23). Spruce Falls Power and Paper Company Ltd.. (Date: 2-5-1991).

Company: 0001340009 Cntr.pt.: 01 Prod. Date	T/day	Daily flow m3/day	Hexachloro-ethane mg/tonne	Hexachloro-butadiene mg/tonne	Hexachloro-yclopentadien mg/tonne	1,2,3-Trichloro-benzene mg/tonne	1,2,4-Trichloro-benzene mg/tonne	2,4,5-Trichloro-toluene mg/tonne	1,2,3,4-Tetra-chlorobenzene mg/tonne	1,2,3,5-Tetra-chlorobenzene mg/tonne
Jan/90	1,115	75,556	-	-	-	-	-	-	-	-
Feb/90	1,087	78,323	-	-	-	-	-	-	-	-
Mar/90	1,071	84,330	-	-	-	-	-	-	-	-
Apr/90	1,077	84,152	-	-	-	-	-	-	-	-
May/90	1,039	82,384	-	-	-	-	-	-	-	-
Jun/90	1,028	91,483	-	-	-	-	-	-	-	-

Company: 0001340009 Cntr.pt.: 01 Prod. Date	T/day	Daily flow m3/day	1,2,4,5-Tetra-chlorobenzene mg/tonne	Penta-chlorobenzene mg/tonne	Hexa-chlorobenzene mg/tonne	Octachloro-styrene mg/tonne
Jan/90	1,115	75,556	-	-	-	-
Feb/90	1,087	78,323	-	-	-	-
Mar/90	1,071	84,330	-	-	-	-
Apr/90	1,077	84,152	-	-	-	-
May/90	1,039	82,384	-	-	-	-
Jun/90	1,028	91,483	-	-	-	-

Table 6b. Chlorinated dioxins, dibenzofuranes and PCB's (ATG(23). Spruce Falls Power and Paper Company Ltd.. (Date: 2-5-1991).

Company: 0001340009 Cntr.pt.: 01 Prod. Date	T/day	Daily flow m3/day	2,3,7,8-TCDD µg/tonne	Total TCDD µg/tonne	Total TCDF µg/tonne	Total PCDD µg/tonne	Total PCDF µg/tonne	Total HxCDD µg/tonne	Total HxCDF µg/tonne	Total HpCDD µg/tonne
Jan/90	1,136	74,549	-	-	-	-	-	-	-	-
Mar/90	1,071	84,330	-	-	-	-	-	-	-	-
May/90	1,039	82,384	-	-	-	-	-	-	-	-

Company: 0001340009 Cntr.pt.: 01 Prod. Date	T/day	Daily flow m3/day	Total HpCDF µg/tonne	OCDD µg/tonne	OCDF µg/tonne	Total PCB's µg/tonne
Jan/90	1,136	74,549	-	47.2	3.3	-
Mar/90	1,071	84,330	-	62.2	-	-
May/90	1,039	82,384	-	17.4	-	-

Table 7b. Fatty and resin acids (ATG 26). Spruce Falls Power and Paper Company Ltd.. (Date: 2-5-1991).

Company: 0001340009 Cntr.pt.: 01 Prod. Date	T/day	Daily flow m3/day	Oleic acid g/tonne	Pimaric acid g/tonne	Abietic acid g/tonne	Dehydro-abietic acid g/tonne	Isopimaric acid g/tonne	Levopimaric acid g/tonne	Neoabietic acid g/tonne	hlorodehydro-abietic acid g/tonne
Jan/90	1,115	75,556	27.7	17.4	195.0	175.0	61.4	-	196.2	4.9
Feb/90	1,087	78,323	12.5	-	122.2	160.2	35.2	-	169.3	-
Mar/90	1,071	84,330	13.6	10.9	142.6	155.2	43.4	-	256.3	3.0
Apr/90	1,077	84,152	6.6	4.5	52.4	104.5	18.1	-	71.7	-
May/90	1,039	82,384	10.6	5.8	59.2	154.3	24.5	-	36.2	-
Jun/90	1,028	91,483	21.2	5.5	71.3	135.9	25.3	-	54.8	-

Company: 0001340009 Cntr.pt.: 01 Prod. Date	T/day	Daily flow m3/day	Dichlorodehydr abietic acid g/tonne	Total resin acids g/tonne	Total resin acids Kg/day	Total resin acids <mg/l>
Jan/90	1,115	75,556	-	649.9	725	9.59
Feb/90	1,087	78,323	-	486.9	529	6.76
Mar/90	1,071	84,330	-	611.4	655	7.76
Apr/90	1,077	84,152	-	251.1	270	3.21
May/90	1,039	82,384	-	279.9	291	3.53
Jun/90	1,028	91,483	-	292.8	301	3.29

Values for dehydroabietic acid and dichlorodehydroabietic acid are monthly averages

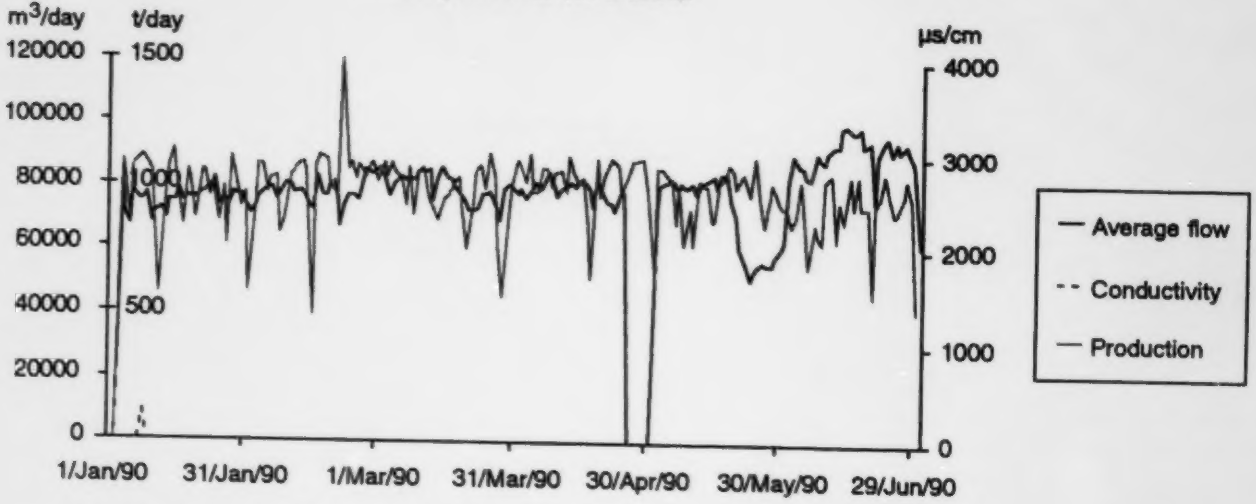
Table 8b. Metals (ATG 9 &12). Spruce Falls Power and Paper Company Ltd.. (Date: 2-5-1991).

Company 00013400C Date	Prod. T/day	Daily flow m3/day	Berylium g/tonne	Aluminium g/tonne	Copper g/tonne	Zinc g/tonne	Chromium g/tonne	Nickel g/tonne	Molybdenum g/tonne	Cobalt g/tonne
Jan/90	1,115	75,556	-	11	2.0	7.1	-	-	-	-
Feb/90	1,087	78,323	-	10	0.7	8.8	-	0.7	-	-
Mar/90	1,071	84,330	-	11	0.8	10.4	-	-	-	-
Apr/90	1,077	84,152	-	19	0.8	8.6	-	-	-	-
May/90	1,039	82,384	-	25	1.6	8.1	1.6	-	-	-
Jun/90	1,028	91,483	-	23	1.8	10.1	-	-	-	-

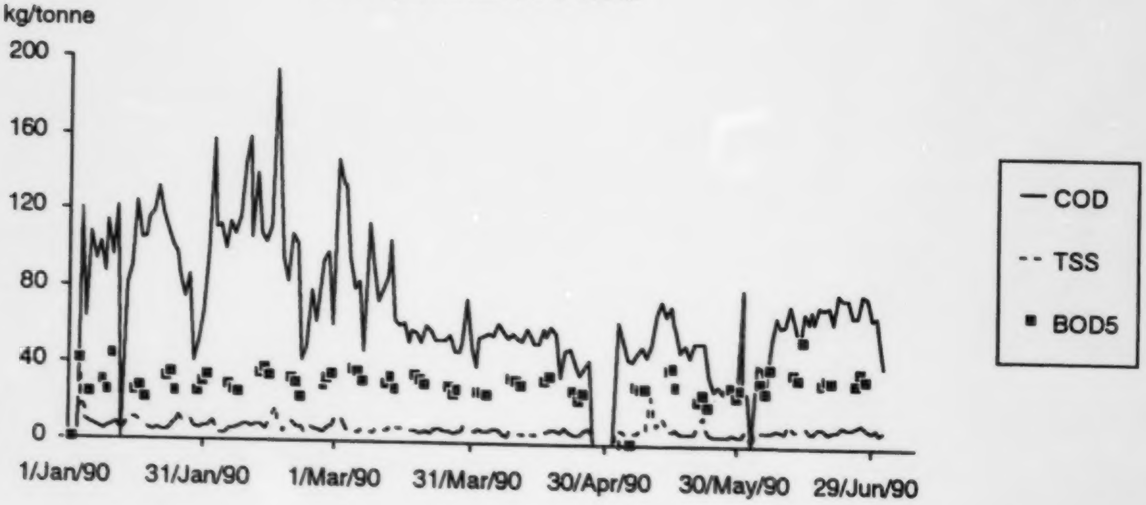
Company 00013400C Date	Prod T/day	Daily flow m3/day	Vanadium g/tonne	Silver g/tonne	Lead g/tonne	Cadmium g/tonne	Thallium g/tonne	Mercury g/tonne
Jan/90	1,115	75,556	-	-	2.0	-	-	-
Feb/90	1,087	78,323	-	-	2.2	0.22	-	-
Mar/90	1,071	84,330	-	-	-	-	-	-
Apr/90	1,077	84,152	-	-	-	-	-	-
May/90	1,039	82,384	-	-	-	-	-	-
Jun/90	1,028	91,483	-	-	-	-	-	-

Values for aluminium and zink are monthly averages.

Average flow, Production and Conductivity data from Spruce Falls Power and Paper Company Ltd., Control point 0100 (17-5-1991).



TSS, COD and BOD data from Spruce Falls Power and Paper Company Ltd., Control point 0100 (17-5-1991).



Corrugating Sub-sector

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Table 1b. Halogenated volatiles (ATG16). Domtar Inc., Containerboard Div. (Trenton). (Date: 29-4-1991).

Company: 0000140608
Cntr.pt.: 01

	Prod. T/day	Daily flow m3/day	Chloromethane mg/tonne	Chloroethylene mg/tonne	Bromomethane mg/tonne	Bromodichloromethane mg/tonne	Dichloromethane mg/tonne	1,1-Dichloroethane mg/tonne	1,2-Dichloroethane mg/tonne	1,1-Dichloroethylene mg/tonne
Jan/90	336	3,860	-	-	-	-	-	-	-	-
Feb/90	348	3,957	-	-	-	-	-	-	-	-
Mar/90	364	3,754	-	-	-	-	-	-	-	-
Apr/90	230	3,805	-	-	-	-	-	-	-	-
May/90	374	4,046	-	-	-	-	-	-	-	-
Jun/90	382	4,401	-	-	-	-	-	-	-	-

Company: 0000140608
Cntr.pt.: 01

	Prod. T/day	Daily flow m3/day	trans-1,2-Dichloroethylene mg/tonne	1,2-Dichloropropane mg/tonne	cis-1,3-Dichloropropylene mg/tonne	trans-1,3-Dichloropropylene mg/tonne	Dibromoethylene mg/tonne	Trichloromethane mg/tonne	Dibromochloromethane mg/tonne	Tribromomethane mg/tonne	1,1,2-Trichloroethane mg/tonne
Jan/90	336	3,860	-	-	-	-	-	0	-	-	-
Feb/90	348	3,957	-	-	-	-	-	0	-	-	-
Mar/90	364	3,754	-	-	-	-	-	-	-	-	-
Apr/90	230	3,805	-	-	-	-	-	-	-	-	-
May/90	374	4,046	-	-	-	-	-	-	-	-	-
Jun/90	382	4,401	-	-	-	-	-	0	-	-	0

Company: 0000140608
Cntr.pt.: 01

	Prod. T/day	Daily flow m3/day	Trichloroethylene mg/tonne	Trifluorochloromethane mg/tonne	Tetrachloromethane mg/tonne	1,1,2,2-Tetrachloroethane mg/tonne	Tetrachloroethylene mg/tonne	Chlorobenzene mg/tonne	1,2-Dichlorobenzene mg/tonne	1,3-Dichlorobenzene mg/tonne	1,4-Dichlorobenzene mg/tonne
Jan/90	336	3,860	-	-	-	-	-	-	-	-	-
Feb/90	348	3,957	-	-	-	-	-	-	-	-	-
Mar/90	364	3,754	-	-	-	-	-	-	-	-	-
Apr/90	230	3,805	-	-	-	-	-	-	-	-	-
May/90	374	4,046	-	-	-	-	-	-	-	-	-
Jun/90	382	4,401	-	-	-	-	-	-	-	-	-

Table 2b. Nonhalogenated volatiles (ATG17). Domtar Inc., Containerboard Div. (Trenton). (Date: 29-4-1991).

Company: 0000140608
Cntr.pt.: 01

Date	Prod. T/day	Daily flow m3/day	Styrene mg/tonne	Benzene mg/tonne	m,p-Xylene mg/tonne	o-Xylene mg/tonne	Toluene mg/tonne
Jan/90	336	3,860	-	-	-	-	-
Feb/90	348	3,957	-	0	-	-	-
Mar/90	364	3,754	-	-	-	-	-
Apr/90	230	3,805	-	-	-	-	-
May/90	374	4,046	-	-	-	-	-
Jun/90	382	4,401	-	-	-	-	-

Table 9b. Inorganics (ATG 3, 4, 6, 7 & 15). Domtar Inc., Containerboard Div. (Trenton). (Date: 29-4-1991).

Company: 0000140608
Cntr.pt.: 01

Date	Prod. T/day	Av. flow m3/day	pH	Conductivity µs/cm	NH3 + NH4 g/tonne	NO2+NO3 g/tonne	Total-N g/tonne	Total-P g/tonne	Sulphide g/tonne
Jan/90	322	3,702	8.0	1178	3	6	39	2	-
Feb/90	316	3,950	7.9	1099	1	7	39	19	-
Mar/90	331	3,865	7.9	962	8	6	114	15	-
Apr/90	310	3,827	7.7	1011	1	6	106	15	-
May/90	340	4,027	7.7	949	1	4	82	12	-
Jun/90	341	4,330	8.0	1040	1	4	61	8	-

Table 10b. Group and unspecific variables (ATG 1, 5, 8, PP1-3). Domtar Inc., Containerboard Div. (Trenton). (Date: 29-4-1991).

Company: 0000140608
Cntr.pt.: 01

Date	Prod. T/day	Av. flow m3/tonne	BOD5 Kg/tonne	AOX Kg/tonne	COD Kg/tonne	DOC Kg/tonne	TOC Kg/tonne	TSS Kg/tonne	VSS Kg/tonne	COD/BOD
Jan/90	322	11	13.0	-	30.5	-	-	3.2	-	2.3
Feb/90	316	13	13.8	-	32.9	-	-	2.0	-	2.4
Mar/90	331	12	13.7	-	29.0	-	-	1.5	-	2.1
Apr/90	310	12	15.2	-	32.7	-	-	1.2	-	2.2
May/90	340	12	15.8	-	27.6	-	-	1.4	-	1.8
Jun/90	341	13	23.4	-	33.7	-	-	1.3	-	1.4

Table 3b. Extractable base neutrals (ATG19). Domtar Inc., Containerboard Div. (Trenton). (Date: 29-4-1991).

Company: 0000140608

Date	Cntr.pt.: 01 Prod. T/day	Daily flow m3/day	Naphthalene mg/tonne	1-Methyl-naphthalene mg/tonne	2-Methyl-naphthalene mg/tonne	1-Chloro-naphthalene mg/tonne	2-Chloro-naphthalene mg/tonne	Anthracene mg/tonne	Benz[a]-anthracene mg/tonne	Dibenz[a] anthracene mg/tonne
Jan/90	336	3,860	-	-	-	-	-	-	-	-
Feb/90	348	3,957	-	-	-	-	-	-	-	-
Mar/90	364	3,754	-	-	-	-	-	-	-	-
Apr/90	230	3,805	-	-	-	-	-	-	-	-
May/90	374	4,046	-	-	-	-	-	-	-	-
Jun/90	382	4,401	-	-	-	-	-	-	-	-

Company: 0000140608

Date	Cntr.pt.: 01 Prod. T/day	Daily flow m3/day	Phenan-threne mg/tonne	Acenaph-thene mg/tonne	Acenaph-thylene mg/tonne	5-Nitro-ace-naphthene mg/tonne	Chrysene mg/tonne	Fluor-anthene mg/tonne	Benz[b]-fluoranthene mg/tonne	Benz[k] fluoranthene mg/tonne	Fluorene mg/tonne
Jan/90	336	3,860	-	-	-	-	-	-	-	-	-
Feb/90	348	3,957	-	-	-	-	-	-	-	-	-
Mar/90	364	3,754	-	-	-	-	-	-	-	-	-
Apr/90	230	3,805	-	-	-	-	-	-	-	-	-
May/90	374	4,046	-	-	-	-	-	-	-	-	-
Jun/90	382	4,401	-	-	-	-	-	-	-	-	-

Company: 0000140608

Date	Cntr.pt.: 01 Prod. T/day	Daily flow m3/day	Pyrene mg/tonne	Benz[a]-pyrene mg/tonne	ndeno[1,2,3-cd pyrene mg/tonne	Perylene mg/tonne	Benz[g,h,i]-perylene mg/tonne	Indole mg/tonne	Camphene mg/tonne
Jan/90	336	3,860	-	-	-	-	-	-	-
Feb/90	348	3,957	-	-	-	-	-	-	-
Mar/90	364	3,754	-	-	-	-	-	-	-
Apr/90	230	3,805	-	-	-	-	-	-	-
May/90	374	4,046	-	-	-	-	-	-	-
Jun/90	382	4,401	-	-	-	-	-	-	-

Table 4b. Acidic extractables (ATG20). Domtar Inc., Containerboard Div. (Trenton). (Date: 29-4-1991).

Company: 0000140608

Date	Cntr.pt.: 01 Prod. T/day	Daily flow m3/day	Phenol mg/tonne	m-Cresol mg/tonne	o-Cresol mg/tonne	p-Cresol mg/tonne	2,4-xylenol mg/tonne	4-Chloro-m-cresol mg/tonne	2-Chloro-phenol mg/tonne	2,4-Dichloro-phenol mg/tonne
Jan/90	336	3,860	0	-	0	-	-	-	-	-
Feb/90	348	3,957	0	-	0	-	-	-	-	-
Mar/90	364	3,754	0	-	0	-	-	-	-	-
Apr/90	230	3,805	0	-	0	-	-	-	-	-
May/90	374	4,046	0	-	0	-	-	-	-	-
Jun/90	382	4,401	0	-	0	-	-	-	-	-

Company: 0000140608

Date	Cntr.pt.: 01 Prod. T/day	Daily flow m3/day	2,6-Dichloro-phenol mg/tonne	2,3,4-Tri-chlorophenol mg/tonne	2,3,5-Tri-chlorophenol mg/tonne	2,4,5-Tri-chlorophenol mg/tonne	2,4,6-Tri-chlorophenol mg/tonne	2,3,4,5-Tetra-chlorophenol mg/tonne	2,3,4,6-Tetra-chlorophenol mg/tonne	2,3,5,6-Tetra-chlorophenol mg/tonne	Penta-chlorophenol mg/tonne
Jan/90	336	3,860	-	-	-	-	-	-	-	-	-
Feb/90	348	3,957	-	-	-	-	-	-	-	-	-
Mar/90	364	3,754	-	-	-	-	-	-	-	-	-
Apr/90	230	3,805	-	-	-	-	-	-	-	-	-
May/90	374	4,046	-	-	-	-	-	-	-	-	0
Jun/90	382	4,401	-	-	-	-	-	-	-	-	-

Company: 0000140608

Date	Cntr.pt.: 01 Prod. T/day	Daily flow m3/day	4-Nitro-phenol mg/tonne	2,4-Dinitro-phenol mg/tonne	4,6-Dinitro-o-cresol mg/tonne
Jan/90	336	3,860	-	-	-
Feb/90	348	3,957	-	-	-
Mar/90	364	3,754	-	-	-
Apr/90	230	3,805	-	-	-
May/90	374	4,046	-	-	-
Jun/90	382	4,401	-	-	-

Table 5b. Chlorinated, neutrals (ATG(23). Domtar Inc., Containerboard Div. (Trenton). (Date: 29-4-1991).

Company: 0000140608 Cntr.pt.: 01 Prod. Date	T/day	Daily flow m3/day	Hexachloro-ethane mg/tonne	Hexachloro-butadiene mg/tonne	Hexachloro-yclopentadien mg/tonne	1,2,3-Trichloro-benzene mg/tonne	1,2,4-Trichloro-benzene mg/tonne	2,4,5-Trichloro-toluene mg/tonne	1,2,3,4-Tetra-chlorobenzene mg/tonne	1,2,3,5-Tetra-chlorobenzene mg/tonne
Jan/90	336	3,860	-	-	-	-	0.0	-	-	-
Feb/90	348	3,957	-	-	-	-	-	-	-	-
Mar/90	364	3,754	-	-	-	-	-	-	-	-
Apr/90	230	3,805	-	-	-	-	-	-	-	-
May/90	374	4,046	-	-	-	-	-	-	-	-
Jun/90	382	4,401	-	-	-	0.0	-	-	-	-

Company: 0000140608 Cntr.pt.: 01 Prod. Date	T/day	Daily flow m3/day	1,2,4,5-Tetra-chlorobenzene mg/tonne	Penta-chlorobenzene mg/tonne	Hexa-chlorobenzene mg/tonne	Octachloro-styrene mg/tonne
Jan/90	336	3,860	-	-	-	-
Feb/90	348	3,957	-	-	-	-
Mar/90	364	3,754	-	-	-	-
Apr/90	230	3,805	-	-	-	-
May/90	374	4,046	-	-	-	-
Jun/90	382	4,401	-	-	-	-

Table 6b. Chlorinated dioxins, dibenzofuranes and PCB's (ATG(23). Domtar Inc., Containerboard Div. (Trenton). (Date: 29-4-1991).

Company: 0000140608 Cntr.pt.: 01 Prod. Date	T/day	Daily flow m3/day	2,3,7,8-TCDD µgtonne	Total TCDD µgtonne	Total TCDF µgtonne	Total PCDD µgtonne	Total PCDF µgtonne	Total HxCDD µgtonne	Total HxCDF µgtonne	Total HpCDD µgtonne
Apr/90	230	3,805	-	-	0.0	-	-	0.0	0.0	0.0
	-		-	-	-	-	-	-	-	-
	-		-	-	-	-	-	-	-	-
	-		-	-	-	-	-	-	-	-
	-		-	-	-	-	-	-	-	-
	-		-	-	-	-	-	-	-	-

Company: 0000140608 Cntr.pt.: 01 Prod. Date	T/day	Daily flow m3/day	Total HpCDF µg/tonne	OCDD µg/tonne	OCDF µg/tonne	Total PCB's µg/tonne
Apr/90	230	3,805	0.0	0.0	0.0	-
	-		-	-	-	-
	-		-	-	-	-
	-		-	-	-	-
	-		-	-	-	-
	-		-	-	-	-

Table 7b. Fatty and resin acids (ATG 26). Domtar Inc., Containerboard Div. (Trenton). (Date: 29-4-1991).

Company: 0000140608 Cntr.pt.: 01 Prod. Date	T/day	Daily flow m3/day	Oleic acid g/tonne	Pimaric acid g/tonne	Abietic acid g/tonne	Dehydro-abietic acid g/tonne	Isopimaric acid g/tonne	Levopimaric acid g/tonne	Neoabietic acid g/tonne	Chlorodehydro-abietic acid g/tonne
Jan/90	336	3,860	0.0	0.0	0.0	7.4	0.0	-	-	-
Feb/90	348	3,957	0.0	0.0	0.0	11.5	0.0	-	-	0.0
Mar/90	364	3,754	0.0	0.0	0.0	13.0	0.0	-	-	-
Apr/90	230	3,805	0.0	0.0	0.0	19.4	0.0	-	-	-
May/90	374	4,046	0.0	0.0	0.0	14.5	0.0	-	0.0	0.0
Jun/90	382	4,401	0.0	0.0	0.0	16.2	0.0	-	0.0	0.0

Company: 0000140608 Cntr.pt.: 01 Prod. Date	T/day	Daily flow m3/day	Dichlorodehydr abietic acid g/tonne	Total resin acids g/tonne	Total resin acids Kg/day	Total resin acids <mg/l>
Jan/90	336	3,860	-	7.4	2	0.64
Feb/90	348	3,957	-	11.5	4	1.01
Mar/90	364	3,754	-	13.0	5	1.26
Apr/90	230	3,805	-	19.4	4	1.17
May/90	374	4,046	-	14.5	5	1.34
Jun/90	382	4,401	-	16.2	6	1.41

Values for dehydroabietic acid and dichlorodehydroabietic acid are monthly averages

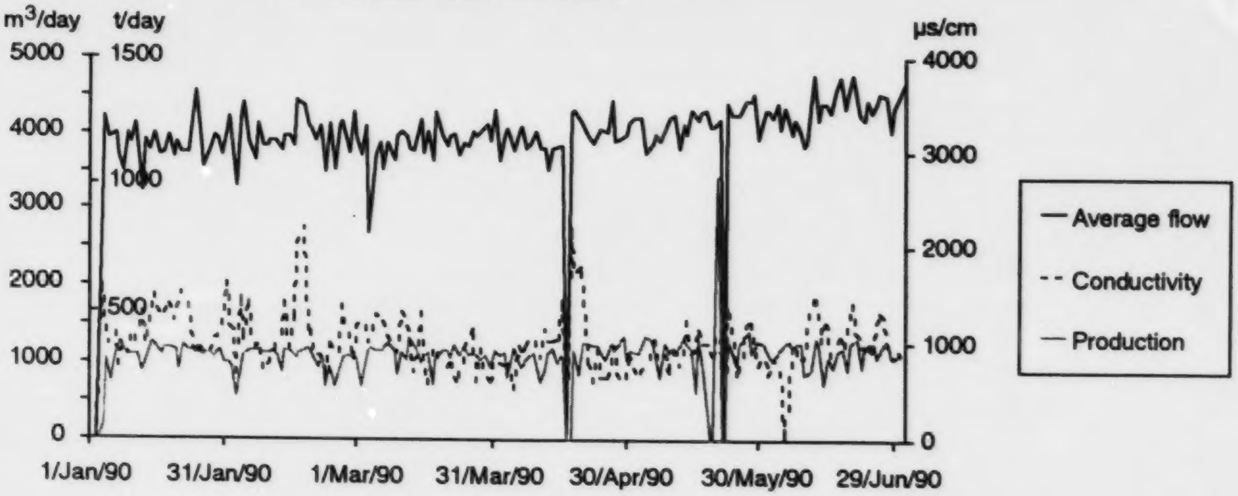
Table 6b. Metals (ATG 9 &12). Domtar Inc., Containerboard Div. (Trenton). (Date: 29-4-1991).

Company 00001406C	Prod. T/day	Daily flow m3/day	Berylium g/tonne	Aluminium g/tonne	Copper g/tonne	Zinc g/tonne	Chromium g/tonne	Nickel g/tonne	Molybdenum g/tonne	Cobalt g/tonne
Date										
Jan/90	336	3,860	-	30	0.0	1.7	-	0.0	-	-
Feb/90	348	3,957	-	35	0.0	2.2	0.0	0.0	-	-
Mar/90	364	3,754	-	38	0.0	1.7	-	-	-	-
Apr/90	230	3,805	-	55	0.0	2.9	0.0	-	-	-
May/90	374	4,046	-	31	0.0	1.5	0.0	-	-	-
Jun/90	382	4,401	-	29	0.0	1.3	-	-	-	-

Company 00001406C	Prod. T/day	Daily flow m3/day	Vanadium g/tonne	Silver g/tonne	Lead g/tonne	Cadmium g/tonne	Thallium g/tonne	Mercury g/tonne
Date								
Jan/90	336	3,860	-	-	-	-	-	0.00
Feb/90	348	3,957	-	-	-	0.00	-	0.00
Mar/90	364	3,754	-	-	-	0.00	-	-
Apr/90	230	3,805	-	-	-	-	-	-
May/90	374	4,046	-	-	-	0.00	-	0.00
Jun/90	382	4,401	-	-	-	-	-	-

Values for aluminium and zink are monthly averages.

Average flow, Production and Conductivity data from Domtar Inc., Containerboard Div. (Trenton), Control point 0100 (14-5-1991).



TSS, COD and BOD5 data from Domtar Inc., Containerboard Div. (Trenton), Control point 0100 (14-5-1991).

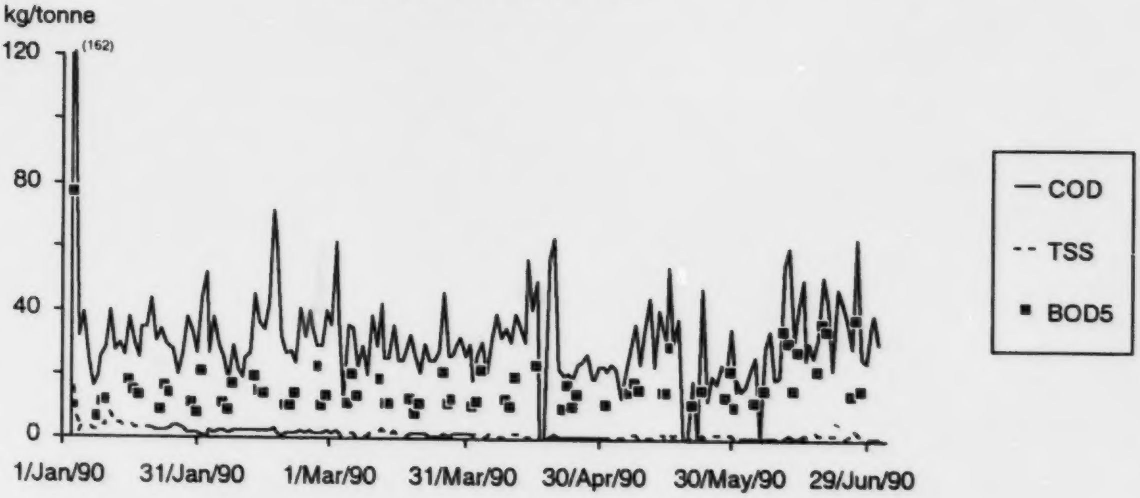


Table 1b. Halogenated volatiles (ATG16). MacMillan Bloedel Ltd. (Sturgeon Falls).. (Date: 29-4-1991).

Company: 0001530005

Cntr.pt.: 12 Prod. T/day		Daily flow m3/day	Chloro-methane mg/tonne	Chloro-ethylene mg/tonne	Bromo-methane mg/tonne	Bromodi-chloromethane mg/tonne	Dichloro-methane mg/tonne	1,1-Dichloro-ethane mg/tonne	1,2-Dichloro-ethane mg/tonne	1,1-Dichloro-ethylene mg/tonne
Jan/90	313	15,979	-	-	-	-	-	-	-	-
Feb/90	316	13,142	-	-	-	-	-	-	-	-
Mar/90	340	13,521	-	-	-	-	-	-	-	-
Apr/90	283	13,466	-	-	-	-	-	-	-	-
May/90	341	15,086	-	-	-	-	-	-	-	-
Jun/90	324	14,929	-	-	-	-	-	-	-	-

Company: 0001530005

Cntr.pt.: 12 Prod. T/day		Daily flow m3/day	trans-1,2-Di-chloroethylene mg/tonne	1,2-Dichloro-propane mg/tonne	cis-1,3-Di-chloropropylene mg/tonne	trans-1,3-Di-chloropropylene mg/tonne	Dibromo-ethylene mg/tonne	Trichloro-methane mg/tonne	Dibromo-chloromethane mg/tonne	Tribromo-methane mg/tonne	1,1,2-Tri-chloroethane mg/tonne
Jan/90	313	15,979	-	-	-	-	-	-	-	-	-
Feb/90	316	13,142	-	-	-	-	-	-	-	-	-
Mar/90	340	13,521	-	-	-	-	-	-	-	-	-
Apr/90	283	13,466	-	-	-	-	-	-	-	-	-
May/90	341	15,086	-	-	-	-	-	-	-	-	-
Jun/90	324	14,929	-	-	-	-	-	-	-	-	-

Company: 0001530005

Cntr.pt.: 12 Prod. T/day		Daily flow m3/day	Trichloro-ethylene mg/tonne	Trifluoro-chloromethane mg/tonne	Tetrachloro-methane mg/tonne	1,1,2,2-Tetra-chloroethane mg/tonne	Tetrachloro-ethylene mg/tonne	Chloro-benzene mg/tonne	1,2-Dichloro-benzene mg/tonne	1,3-Dichloro-benzene mg/tonne	1,4-Dichloro-benzene mg/tonne
Jan/90	313	15,979	-	-	-	-	-	-	-	-	-
Feb/90	316	13,142	-	-	-	-	-	-	-	-	-
Mar/90	340	13,521	-	-	-	-	-	-	-	-	-
Apr/90	283	13,466	-	-	-	-	-	-	-	-	-
May/90	341	15,086	-	-	-	-	-	-	-	-	-
Jun/90	324	14,929	-	-	-	-	-	-	-	-	-

Table 2b. Nonhalogenated volatiles (ATG17). MacMillan Bloedel Ltd. (Sturgeon Falls).. (Date: 29-4-1991).

Company: 0001530005

Cntr.pt.: 12 Prod. T/day		Daily flow m3/day	Styrene mg/tonne	Benzene mg/tonne	m,p-Xylene mg/tonne	o-Xylene mg/tonne	Toluene mg/tonne
Date							
Jan/90	313	15,979	-	366	-	-	256
Feb/90	316	13,142	-	940	-	-	2,892
Mar/90	340	13,521	-	-	-	-	-
Apr/90	283	13,466	-	433	-	-	267
May/90	341	15,086	-	-	-	-	-
Jun/90	324	14,929	-	-	-	-	-

Table 9b. Inorganics (ATG 3, 4, 6, 7 & 15). MacMillan Bloedel Ltd. (Sturgeon Falls).. (Date: 29-4-1991).

Company: 0001530005

Cntr.pt.: 12 Prod. T/day		Av. flow m3/day	pH	Conductivity µs/cm	NH3 + NH4 g/tonne	NO2+NO3 g/tonne	Total-N g/tonne	Total-P g/tonne	Sulphide g/tonne
Date									
Jan/90	259	13,745	4.8	1756.7	11	14,861	1,432	130	-
Feb/90	301	13,995	5.1	1735.0	9	10,583	1,073	61	-
Mar/90	310	12,674	5.1	1771.1	647	12,866	1,123	104	-
Apr/90	275	13,929	5.3	1895.3	102	25,108	532	94	-
May/90	293	13,815	5.0	1856.1	693	13,598	663	87	-
Jun/90	279	13,727	5.4	1971.8	975	10,957	1,279	82	-

Table 10b. Group and unspecific variables (ATG 1, 5, 8, PP1-3). MacMillan Bloedel Ltd. (Sturgeon Falls).. (Date: 29-4-1991).

Company: 0001530005

Cntr.pt.: 12 Prod. T/day		Av. flow m3/tonne	BOD5 Kg/tonne	AOX Kg/tonne	COD Kg/tonne	DOC Kg/tonne	TOC Kg/tonne	TSS Kg/tonne	VSS Kg/tonne	DOC/BOD
Date										
Jan/90	259	53	122.1	-	-	161.3	-	8.2	-	1.3
Feb/90	301	46	123.1	-	-	125.8	-	9.2	-	1.0
Mar/90	310	41	121.3	-	-	119.3	-	9.4	-	1.0
Apr/90	275	51	154.9	-	-	132.1	-	10.6	-	0.9
May/90	293	47	135.4	-	-	108.8	-	8.1	-	0.8
Jun/90	279	49	114.0	-	-	106.4	-	7.3	5.5	0.9

Table 3b. Extractable base neutrals (ATG19). MacMillan Bloedel Ltd. (Sturgeon Falls).. (Date: 29-4-1991).

Company: 0001530005
Cntr.pt.: 12

Date	Prod. T/day	Daily flow m3/day	Naphthalene mg/tonne	1-Methyl-naphthalene mg/tonne	2-Methyl-naphthalene mg/tonne	1-Chloro-naphthalene mg/tonne	2-Chloro-naphthalene mg/tonne	Anthracene mg/tonne	Benz[a]-anthracene mg/tonne	Dibenz[a] anthracene mg/tonne
Jan/90	313	15,979	-	-	-	-	-	-	-	-
Feb/90	316	13,142	-	-	-	-	-	-	-	-
Mar/90	340	13,521	-	-	-	-	-	-	-	-
Apr/90	283	13,466	-	-	-	-	-	-	-	-
May/90	341	15,086	-	-	-	-	-	-	-	-
Jun/90	324	14,929	-	-	-	-	-	-	-	-

Company: 0001530005
Cntr.pt.: 12

Date	Prod. T/day	Daily flow m3/day	Phenanthrene mg/tonne	Acenaphthene mg/tonne	Acenaphthylene mg/tonne	5-Nitro-acenaphthene mg/tonne	Chrysene mg/tonne	Fluoranthene mg/tonne	Benz[b]-fluoranthene mg/tonne	Benz[k] fluoranthene mg/tonne	Fluorene mg/tonne
Jan/90	313	15,979	-	-	-	-	-	-	-	-	-
Feb/90	316	13,142	-	-	-	-	-	-	-	-	-
Mar/90	340	13,521	-	-	-	-	-	-	-	-	-
Apr/90	283	13,466	-	-	-	-	-	-	-	-	-
May/90	341	15,086	-	-	-	-	-	-	-	-	-
Jun/90	324	14,929	-	-	-	-	-	-	-	-	-

Company: 0001530005
Cntr.pt.: 12

Date	Prod. T/day	Daily flow m3/day	Pyrene mg/tonne	Benz[a]-pyrene mg/tonne	ideno[1,2,3-cd pyrene mg/tonne	Perylene mg/tonne	Benz[g,h,i]-perylene mg/tonne	Indole mg/tonne	Camphene mg/tonne
Jan/90	313	15,979	-	-	-	-	-	-	-
Feb/90	316	13,142	-	-	-	-	-	-	-
Mar/90	340	13,521	-	-	-	-	-	-	-
Apr/90	283	13,466	-	-	-	-	-	-	-
May/90	341	15,086	-	-	-	-	-	-	-
Jun/90	324	14,929	-	-	-	-	-	-	-

Table 4b. Acidic extractables (ATG20). MacMillan Bloedel Ltd. (Sturgeon Falls).. (Date: 29-4-1991).

Company: 0001530005
Cntr.pt.: 12

Date	Prod. T/day	Daily flow m3/day	Phenol mg/tonne	m-Cresol mg/tonne	o-Cresol mg/tonne	p-Cresol mg/tonne	2,4-xylenol mg/tonne	4-Chloro-m-cresol mg/tonne	2-Chloro-phenol mg/tonne	2,4-Dichloro-phenol mg/tonne
Jan/90	313	15,979	-	-	-	-	-	-	-	-
Feb/90	316	13,142	9,467	-	-	-	-	-	-	-
Mar/90	340	13,521	176	-	-	-	-	-	-	-
Apr/90	283	13,466	-	-	-	-	-	-	-	-
May/90	341	15,086	-	-	-	-	-	-	-	-
Jun/90	324	14,929	-	-	-	-	-	-	-	-

Company: 0001530005
Cntr.pt.: 12

Date	Prod. T/day	Daily flow m3/day	2,6-Dichloro-phenol mg/tonne	2,3,4-Tri-chlorophenol mg/tonne	2,3,5-Tri-chlorophenol mg/tonne	2,4,5-Tri-chlorophenol mg/tonne	2,4,6-Tri-chlorophenol mg/tonne	2,3,4,5-Tetra-chlorophenol mg/tonne	2,3,4,6-Tetra-chlorophenol mg/tonne	2,3,5,6-Tetra-chlorophenol mg/tonne	Penta-chlorophenol mg/tonne
Jan/90	313	15,979	-	-	-	-	-	-	-	-	-
Feb/90	316	13,142	-	-	-	-	-	-	-	-	-
Mar/90	340	13,521	-	-	-	-	-	-	-	-	-
Apr/90	283	13,466	-	-	-	-	-	-	-	-	-
May/90	341	15,086	-	-	-	-	-	-	-	-	-
Jun/90	324	14,929	-	-	-	-	-	-	-	-	-

Company: 0001530005
Cntr.pt.: 12

Date	Prod. T/day	Daily flow m3/day	4-Nitro-phenol mg/tonne	2,4-Dinitro-phenol mg/tonne	4,6-Dinitro-o-cresol mg/tonne
Jan/90	313	15,979	-	-	-
Feb/90	316	13,142	-	-	-
Mar/90	340	13,521	-	-	-
Apr/90	283	13,466	-	-	-
May/90	341	15,086	-	-	-
Jun/90	324	14,929	-	-	-

Table 5b. Chlorinated, neutrals (ATG(23). MacMillan Bloedel Ltd. (Sturgeon Falls).. (Date: 29-4-1991).

Company: 0001530005 Cntr.pt.: 12 Date	Prod. T/day	Daily flow m3/day	Hexachloro-ethane mg/tonne	Hexachloro-butadiene mg/tonne	Hexachloro-yclopentadien mg/tonne	1,2,3-Trichloro-benzene mg/tonne	1,2,4-Trichloro-benzene mg/tonne	2,4,5-Trichloro-toluene mg/tonne	1,2,3,4-Tetra-chlorobenzene mg/tonne	1,2,3,5-Tetra-chlorobenzene mg/tonne
Jan/90	313	15,979	-	-	-	-	-	-	-	-
Feb/90	316	13,142	-	-	-	-	-	-	-	-
Mar/90	340	13,521	-	-	-	-	-	-	-	-
Apr/90	283	13,466	-	-	-	-	-	-	-	-
May/90	341	15,086	-	-	-	-	-	-	-	-
Jun/90	324	14,929	-	-	-	-	-	-	-	-

Company: 0001530005 Cntr.pt.: 12 Date	Prod. T/day	Daily flow m3/day	1,2,4,5-Tetra-chlorobenzene mg/tonne	Penta-chlorobenzene mg/tonne	Hexa-chlorobenzene mg/tonne	Octachloro-styrene mg/tonne
Jan/90	313	15,979	-	-	-	-
Feb/90	316	13,142	-	-	-	-
Mar/90	340	13,521	-	-	-	-
Apr/90	283	13,466	-	-	-	-
May/90	341	15,086	-	-	-	-
Jun/90	324	14,929	-	-	-	-

Table 6b. Chlorinated dioxins, dibenzofuranes and PCB's (ATG(23). MacMillan Bloedel Ltd. (Sturgeon Falls)..(Date: 29-4-1991)

Company: 0001530005 Cntr.pt.: 12 Date	Prod. T/day	Daily flow m3/day	2,3,7,8-TCDD μgtonne	Total TCDD μgtonne	Total TCDF μgtonne	Total PCDD μgtonne	Total PCDF μgtonne	Total HxCDD μgtonne	Total HxCDF μgtonne	Total HpCDD μgtonne

Company: 0001530005 Cntr.pt.: 12 Date	Prod. T/day	Daily flow m3/day	Total HpCDF μg/tonne	OCDD μg/tonne	OCDF μg/tonne	Total PCB's μg/tonne

Table 7b. Fatty and resin acids (ATG 26). MacMillan Bloedel Ltd. (Sturgeon Falls).. (Date: 29-4-1991).

Company: 0001530005 Cntr.pt.: 12 Date	Prod. T/day	Daily flow m3/day	Oleic acid g/tonne	Pimaric acid g/tonne	Abietic acid g/tonne	Dehydro-abietic acid g/tonne	Isopimaric acid g/tonne	Levopimaric acid g/tonne	Neoabietic acid g/tonne	Chlorodehydro-abietic acid g/tonne
Jan/90	313	15,979	-	-	-	6.0	-	-	-	-
Feb/90	316	13,142	64.0	7.3	-	8.7	70.9	-	-	6.9
Mar/90	340	13,521	24.3	5.5	-	5.0	53.8	46.9	3.1	6.6
Apr/90	283	13,466	5.7	2.6	-	2.0	13.7	-	-	1.9
May/90	341	15,086	0.6	4.3	4.4	18.7	98.1	4.0	5.7	14.1
Jun/90	324	14,929	1.1	2.8	2.3	4.4	11.4	92.2	-	2.7

Company: 0001530005 Cntr.pt.: 12 Date	Prod. T/day	Daily flow m3/day	Dichlorodehydro-abietic acid g/tonne	Total resin acids g/tonne	Total resin acids Kg/day	Total resin acids <mg/l>
Jan/90	313	15,979	-	6.0	2	0.12
Feb/90	316	13,142	-	93.8	30	2.26
Mar/90	340	13,521	-	120.9	41	3.04
Apr/90	283	13,466	-	20.5	6	0.43
May/90	341	15,086	-	149.3	51	3.37
Jun/90	324	14,929	-	115.8	38	2.51

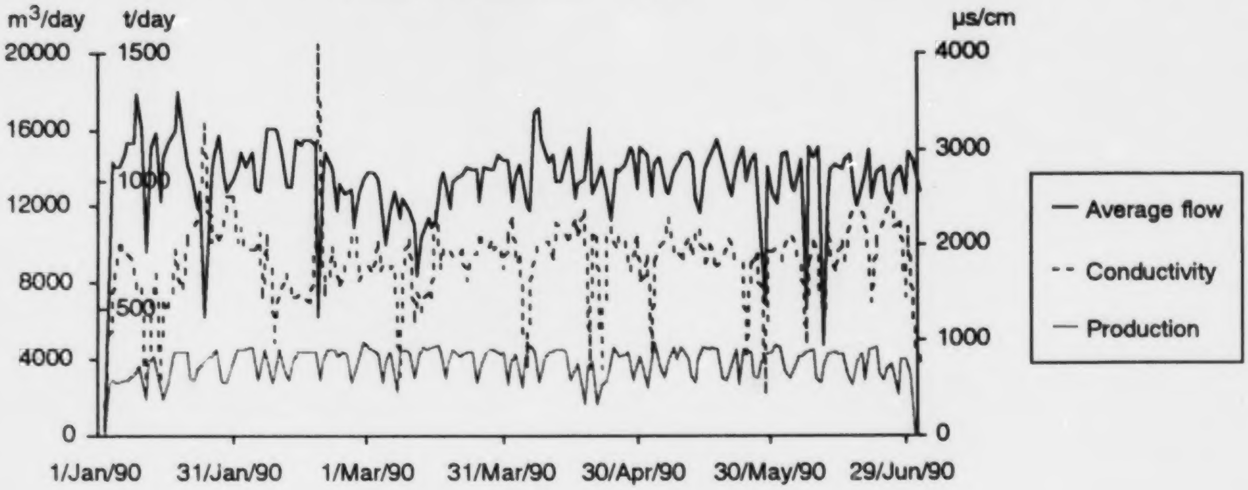
Values for dehydroabietic acid and dichlorodehydroabietic acid are monthly averages

Table 8b. Metals (ATG 9 &12). MacMillan Bloedel Ltd. (Sturgeon Falls).. (Date: 29-4-1991).

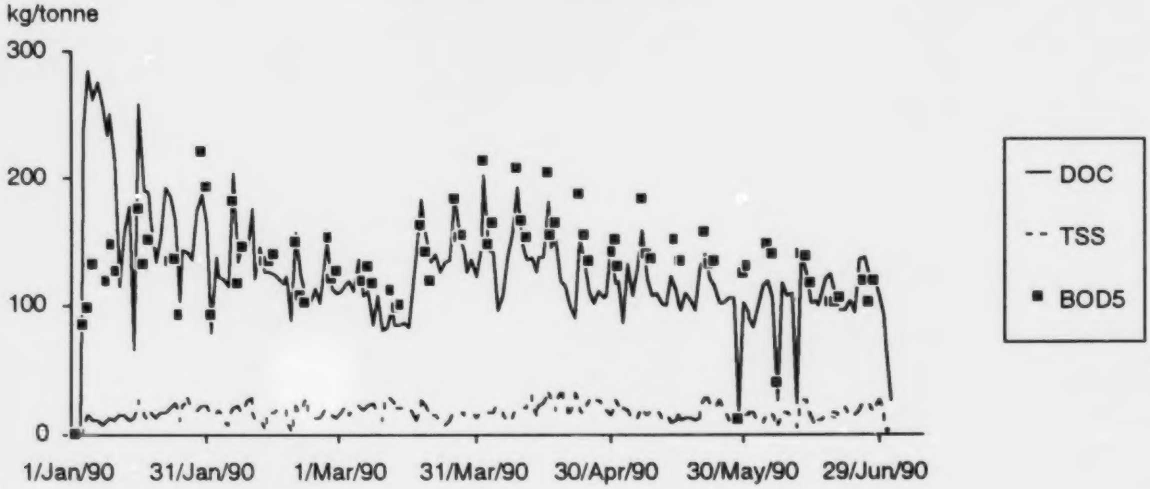
Company 00015300C Date	Prod. T/day	Daily flow m3/day	Berylium g/tonne	Aluminium g/tonne	Copper g/tonne	Zinc g/tonne	Chromium g/tonne	Nickel g/tonne	Molybdenum g/tonne	Cobalt g/tonne
Jan/90	313	15,973	-	51	6	29	-	3	-	-
Feb/90	316	13,142	-	75	-	24	1	1	-	1
Mar/90	340	13,521	-	65	1	22	1	1	-	2
Apr/90	283	13,466	-	59	1	38	-	1	-	1
May/90	341	15,086	-	53	3	21	3	2	-	2
Jun/90	324	14,929	-	49	3	25	2	4	2	2

Company 00015300C Date	Prod. T/day	Daily flow m3/day	Vanadium g/tonne	Silver g/tonne	Lead g/tonne	Cadmium g/tonne	Thallium g/tonne	Mercury g/tonne
Jan/90	313	15,979	3	6	4	4	-	-
Feb/90	316	13,142	2	-	1	1	-	-
Mar/90	340	13,521	2	-	2	-	-	-
Apr/90	283	13,466	1	-	-	2	-	-
May/90	341	15,086	3	-	3	2	-	-
Jun/90	324	14,929	6	1	5	1	2	-

Values for aluminium and zink are monthly averages.



Average flow, Production and Conductivity data from MacMillan Bloedel Ltd. (Sturgeon Falls), Control point 1300 (15-5-1991).



TSS, DOC and BOD5 data from MacMillan Bloedel Ltd. (Sturgeon Falls)., Control point 1300 (15-5-1991).

Deinking-Board-Fine Papers-Tissue Sub-sector

		Page
Beaver Wood Fibre Company Ltd.	Thorold	100
Domtar Inc., Fine Papers Div.	St. Catharines	105
E. B. Eddy Forest Products Ltd.	Ottawa	110
Noranda Forest Inc., Recycled Papers	Thorold	115
Kimberly-Clark Canada Inc.	St. Catharines	120
Kimberly-Clark Canada Inc.	Huntsville	125
Trent Valley, Paperboard Industries Corporation	Trenton	130
Strathcona Paper Company	Napanee	135

Table 1b. Halogenated volatiles (ATG16). Beaver Wood Fibre Company Ltd.. (Date: 29-4-1991).

Company: 0001620004 Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	Chloro-methane mg/tonne	Chloro-ethylene mg/tonne	Bromo-methane mg/tonne	Bromodi-chloromethane mg/tonne	Dichloro-methane mg/tonne	1,1-Dichloro-ethane mg/tonne	1,2-Dichloro-ethane mg/tonne	1,1-Dichloro-ethylene mg/tonne
Jan/90	286	16,600	-	-	-	-	-	-	-	279
Feb/90	233	14,900	1,599	-	576	-	-	54	-	448
Mar/90	310	15,800	673	-	101	-	291	-	-	-
Apr/90	328	14,300	-	-	554	-	-	22	-	174
May/90	318	16,700	-	-	-	-	-	-	-	-
Jun/90	340	15,900	-	-	-	-	-	-	-	1,076

Company: 0001620004 Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	trans-1,2-Di-chloroethylene mg/tonne	1,2-Dichloro-propane mg/tonne	cis-1,3-Di-chloropropylen mg/tonne	trans-1,3-Di-chloropropylen mg/tonne	Dibromo-ethylene mg/tonne	Trichloro-methane mg/tonne	Dibromo-chloromethane mg/tonne	Tribromo-methane mg/tonne	1,1,2-Tri-chloroethane mg/tonne
Jan/90	286	16,600	-	-	-	-	-	-	-	-	-
Feb/90	233	14,900	-	-	-	-	-	73	-	-	-
Mar/90	310	15,800	-	-	-	-	-	112	-	-	-
Apr/90	328	14,300	-	-	-	-	-	166	-	-	-
May/90	318	16,700	-	-	-	-	-	-	-	-	-
Jun/90	340	15,900	-	-	-	-	-	-	-	-	-

Company: 0001620004 Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	Trichloro-ethylene mg/tonne	Trifluoro-chloromethane mg/tonne	Tetrachloro-methane mg/tonne	1,1,2,2-Tetra-chloroethane mg/tonne	Tetrachloro-ethylene mg/tonne	Chloro-benzene mg/tonne	1,2-Dichloro-benzene mg/tonne	1,3-Dichloro-benzene mg/tonne	1,4-Dichloro-benzene mg/tonne
Jan/90	286	16,600	-	-	-	-	-	-	-	-	-
Feb/90	233	14,900	-	-	-	-	-	-	-	-	-
Mar/90	310	15,800	-	-	-	-	-	-	-	-	87
Apr/90	328	14,300	-	-	-	-	-	-	-	-	-
May/90	318	16,700	-	-	-	-	-	-	-	-	-
Jun/90	340	15,900	-	-	-	-	-	-	25	-	-

Table 2b. Nonhalogenated volatiles (ATG17). Beaver Wood Fibre Company Ltd.. (Date: 29-4-1991).

Company: 0001620004 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Styrene mg/tonne	Benzene mg/tonne	m,p-Xylene mg/tonne	o-Xylene mg/tonne	Toluene mg/tonne
Jan/90	286	16,600	-	34	75	42	818
Feb/90	233	14,900	-	-	81	37	723
Mar/90	310	15,800	-	-	95	18	362
Apr/90	328	14,300	-	15	-	17	105
May/90	318	16,700	-	-	-	-	152
Jun/90	340	15,900	-	150	98	-	126

Table 9b. Inorganice (ATG 3, 4, 6, 7 & 15). Beaver Wood Fibre Company Ltd.. (Date: 29-4-1991).

Company: 0001620004 Cntr.pt.: 01 Date	Prod. T/day	Av. flow m3/day	pH	Conductivity µs/cm	NH3 + NH4 g/tonne	NO2+NO3 g/tonne	Total-N g/tonne	Total-P g/tonne	Sulphide g/tonne
Jan/90	143	15,650	7.4	377	4	30	230	5	-
Feb/90	197	15,143	7.3	384	1	20	208	4	-
Mar/90	235	15,400	7.3	374	3	10	70	4	-
Apr/90	242	14,308	7.4	382	2	11	115	4	-
May/90	246	15,319	7.3	379	8	12	187	4	-
Jun/90	288	15,057	7.2	380	1	1	97	8	-

Table 10b. Group and unspecific variables (ATG 1, 5, 8, PP1-3). Beaver Wood Fibre Company Ltd.. (Date: 29-4-1991).

Company: 0001620004 Cntr.pt.: 01 Date	Prod. T/day	Av. flow m3/tonne	BOD5 Kg/tonne	AOX Kg/tonne	COD Kg/tonne	DOC Kg/tonne	TOC Kg/tonne	TSS Kg/tonne	VSS Kg/tonne	DOC/BOD
Jan/90	143	110	13.5	-	-	7.5	-	8.2	-	0.6
Feb/90	197	77	8.6	-	-	5.0	-	3.9	-	0.6
Mar/90	235	66	7.6	-	-	4.5	-	3.4	-	0.6
Apr/90	242	59	7.0	-	-	4.2	-	2.7	-	0.6
May/90	246	62	7.1	-	-	4.4	-	2.8	-	0.6
Jun/90	288	52	6.1	-	-	3.6	-	2.1	-	0.6

Table 3b. Extractable base neutrals (ATG19). Beaver Wood Fibre Company Ltd.. (Date: 29-4-1991).

Company: 0001620004 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Naphthalene mg/tonne	1-Methyl-naphthalene mg/tonne	2-Methyl-naphthalene mg/tonne	1-Chloro-naphthalene mg/tonne	2-Chloro-naphthalene mg/tonne	Anthracene mg/tonne	Benz[a]-anthracene mg/tonne	Dibenz[a] anthracene mg/tonne
Jan/90	286	16,600	-	-	-	-	-	-	-	-
Feb/90	233	14,900	-	-	-	-	-	-	-	-
Mar/90	310	15,800	-	-	-	-	-	-	-	-
Apr/90	328	14,300	-	-	-	-	-	-	-	-
May/90	318	16,700	-	-	-	-	-	-	-	-
Jun/90	340	15,900	47	-	-	-	-	-	-	-

Company: 0001620004 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Phenan-threne mg/tonne	Acenaph-thene mg/tonne	Acenaph-thylene mg/tonne	5-Nitro-ace-naphthene mg/tonne	Chrysene mg/tonne	Fluor-anthene mg/tonne	Benz[b]-fluoranthene mg/tonne	Benz[k] fluoranthene mg/tonne	Fluorene mg/tonne
Jan/90	286	16,600	-	-	-	-	-	-	-	-	-
Feb/90	233	14,900	-	-	-	-	-	-	-	-	-
Mar/90	310	15,800	-	-	-	-	-	-	-	-	-
Apr/90	328	14,300	-	-	-	-	-	-	-	-	-
May/90	318	16,700	-	-	-	-	-	-	-	-	-
Jun/90	340	15,900	-	-	-	-	-	-	-	-	-

Company: 0001620004 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Pyrene mg/tonne	Benz[a]-pyrene mg/tonne	ıdeno[1,2,3-cd pyrene mg/tonne	Perylene mg/tonne	Benz[g,h,i]-perylene mg/tonne	Indole mg/tonne	Camphene mg/tonne
Jan/90	286	16,600	-	-	-	-	-	-	-
Feb/90	233	14,900	-	-	-	-	-	-	-
Mar/90	310	15,800	-	-	-	-	-	-	-
Apr/90	328	14,300	-	-	-	-	-	-	-
May/90	318	16,700	-	-	-	-	-	93	-
Jun/90	340	15,900	-	-	-	-	-	-	-

Table 4b. Acidic extractables (ATG20). Beaver Wood Fibre Company Ltd.. (Date: 29-4-1991).

Company: 0001620004 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Phenol mg/tonne	m-Cresol mg/tonne	o-Cresol mg/tonne	p-Cresol mg/tonne	2,4-xylenol mg/tonne	4-Chloro-m-cresol mg/tonne	2-Chloro-phenol mg/tonne	2,4-Dichloro-phenol mg/tonne
Jan/90	286	16,600	221	-	-	-	-	-	-	-
Feb/90	233	14,900	345	-	-	-	-	-	-	-
Mar/90	310	15,800	418	-	-	-	-	-	-	-
Apr/90	328	14,300	288	26	-	68	-	-	-	-
May/90	318	16,700	252	42	-	-	-	-	-	-
Jun/90	340	15,900	566	182	14	234	-	19	-	-

Company: 0001620004 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	2,6-Dichloro-phenol mg/tonne	2,3,4-Tri-chlorophenol mg/tonne	2,3,5-Tri-chlorophenol mg/tonne	2,4,5-Tri-chlorophenol mg/tonne	2,4,6-Tri-chlorophenol mg/tonne	2,3,4,5-Tetra-chlorophenol mg/tonne	2,3,4,6-Tetra-chlorophenol mg/tonne	2,3,5,6-Tetra-chlorophenol mg/tonne	Penta-chlorophenol mg/tonne
Jan/90	286	16,600	-	-	-	-	-	-	-	-	-
Feb/90	233	14,900	-	-	-	-	-	-	-	-	-
Mar/90	310	15,800	-	-	-	-	-	-	-	-	-
Apr/90	328	14,300	-	-	-	-	-	-	-	-	-
May/90	318	16,700	-	-	-	-	-	-	-	-	-
Jun/90	340	15,900	-	-	-	-	-	-	-	-	-

Company: 0001620004 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	4-Nitro-phenol mg/tonne	2,4-Dinitro-phenol mg/tonne	4,6-Dinitro-o-cresol mg/tonne
Jan/90	286	16,600	-	-	-
Feb/90	233	14,900	-	-	-
Mar/90	310	15,800	-	-	-
Apr/90	328	14,300	-	-	-
May/90	318	16,700	-	-	-
Jun/90	340	15,900	-	-	-

Table 5b. Chlorinated, neutrals (ATG(23). Beaver Wood Fibre Company Ltd.. (Date: 29-4-1991).

Company: 0001620004			Hexachloro-	Hexachloro-	Hexachloro-	1,2,3-Trichloro-	1,2,4-Trichloro-	2,4,5-Trichloro-	1,2,3,4-Tetra-	1,2,3,5-Tetra-
Cntr.pt.: 01	Prod.	Daily flow	ethane	butadiene	cyclopentadien	benzene	benzene	toluene	chlorobenzene	chlorobenzene
	T/day	m3/day	mg/tonne	mg/tonne	mg/tonne	mg/tonne	mg/tonne	mg/tonne	mg/tonne	mg/tonne
Date										
Jan/90	286	16,600	-	-	-	-	0.3	-	-	-
Feb/90	233	14,900	-	-	-	-	0.4	-	-	-
Mar/90	310	15,800	-	-	-	-	0.1	0.2	-	-
Apr/90	328	14,300	-	-	-	-	-	-	-	-
May/90	318	16,700	-	-	-	-	-	-	-	-
Jun/90	340	15,900	-	-	-	-	0.3	-	-	-

Company: 0001620004			1,2,4,5-Tetra-	Penta-	Hexa-	Octachloro-
Cntr.pt.: 01	Prod.	Daily flow	chlorobenzene	chlorobenzene	chlorobenzene	styrene
	T/day	m3/day	mg/tonne	mg/tonne	mg/tonne	mg/tonne
Date						
Jan/90	286	16,600	-	-	-	-
Feb/90	233	14,900	-	-	-	-
Mar/90	310	15,800	-	-	-	-
Apr/90	328	14,300	-	-	-	-
May/90	318	16,700	-	-	-	-
Jun/90	340	15,900	-	-	-	-

Table 6b. Chlorinated dioxins, dibenzofuranes and PCB's (ATG(23). Beaver Wood Fibre Company Ltd.. (Date: 29-4-1991).

Company: 0001620004			2,3,7,8-	Total	Total	Total	Total	Total	Total	Total
Cntr.pt.: 01	Prod.	Daily flow	TCDD	TCDD	TCDF	PCDD	PCDF	HxCDD	HxCDF	HpCDD
	T/day	m3/day	µg/tonne	µg/tonne	µg/tonne	µg/tonne	µg/tonne	µg/tonne	µg/tonne	µg/tonne
Date										
	-		-	-	-	-	-	-	-	-
	-		-	-	-	-	-	-	-	-
	-		-	-	-	-	-	-	-	-
	-		-	-	-	-	-	-	-	-
	-		-	-	-	-	-	-	-	-
	-		-	-	-	-	-	-	-	-

Company: 0001620004			Total			Total
Cntr.pt.: 01	Prod.	Daily flow	HpCDF	OCDD	OCDF	PCB's
	T/day	m3/day	µg/tonne	µg/tonne	µg/tonne	µg/tonne
Date						
	-		-	-	-	-
	-		-	-	-	-
	-		-	-	-	-
	-		-	-	-	-
	-		-	-	-	-
	-		-	-	-	-

Table 7b. Fatty and resin acids (ATG 26). Beaver Wood Fibre Company Ltd.. (Date: 29-4-1991).

Company: 0001620004			Oleic	Pimaric	Abietic	Dehydro-	Isopimaric	Levopimaric	Neoabietic	Chlorodehydro-
Cntr.pt.: 01	Prod.	Daily flow	acid	acid	acid	abietic acid	acid	acid	acid	abietic acid
	T/day	m3/day	g/tonne	g/tonne	g/tonne	g/tonne	g/tonne	g/tonne	g/tonne	g/tonne
Date										
Jan/90	286	16,600	-	0.9	6.7	21.3	6.2	-	-	-
Feb/90	233	14,900	-	1.2	10.6	36.4	7.0	4.0	1.4	-
Mar/90	310	15,800	-	-	-	2.7	2.9	-	-	0.8
Apr/90	328	14,300	0.0	-	2.3	18.8	2.6	-	-	-
May/90	318	16,700	0.6	1.9	6.3	23.1	3.7	-	0.8	0.5
Jun/90	340	15,900	-	1.1	-	17.3	2.0	-	-	-

Company: 0001620004			Dichlorodehydro-	Total resin	Total resin	Total resin
Cntr.pt.: 01	Prod.	Daily flow	abietic acid	acids	acids	acids
	T/day	m3/day	g/tonne	g/tonne	Kg/day	<mg/l>
Date						
Jan/90	286	16,600	-	35.1	10	0.60
Feb/90	233	14,900	-	60.6	14	0.95
Mar/90	310	15,800	-	6.4	2	0.12
Apr/90	328	14,300	-	23.6	8	0.54
May/90	318	16,700	-	36.4	12	0.69
Jun/90	340	15,900	-	20.3	7	0.43

Values for dehydroabietic acid and dichlorodehydroabietic acid are monthly averages

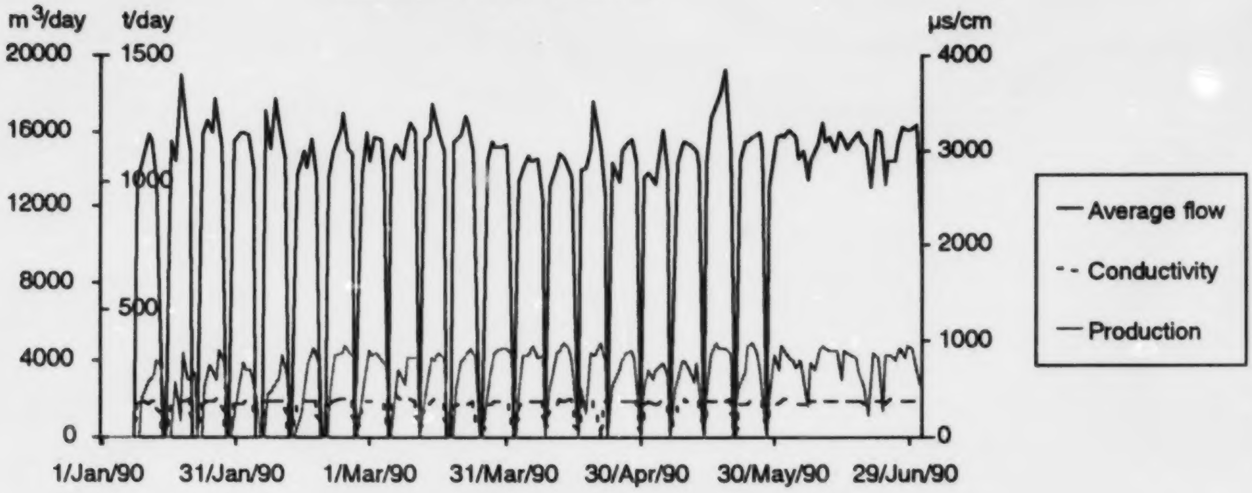
Table 8b. Metals (ATG 9 &12). Beaver Wood Fibre Company Ltd.. (Date: 29-4-1991).

Company 00016200C Date	Prod. T/day	Daily flow m3/day	Berylium g/tonne	Aluminium g/tonne	Copper g/tonne	Zinc g/tonne	Chromium g/tonne	Nickel g/tonne	Molybdenum g/tonne	Cobalt g/tonne
Jan/90	286	16,600	-	43	0.5	2.0	-	0.5	0.3	-
Feb/90	233	14,900	-	42	0.7	3.2	-	-	0.5	-
Mar/90	310	15,800	-	38	0.7	1.8	0.6	0.3	-	-
Apr/90	328	14,300	-	89	1.5	0.7	-	-	0.9	-
May/90	318	16,700	-	33	-	1.3	3.4	-	-	-
Jun/90	340	15,900	-	16	0.2	1.0	-	-	0.8	-

Company 00016200C Date	Prod. T/day	Daily flow m3/day	Vanadium g/tonne	Silver g/tonne	Lead g/tonne	Cadmium g/tonne	Thallium g/tonne	Mercury g/tonne
Jan/90	286	16,600	0.7	-	0.1	0.03	-	-
Feb/90	233	14,900	0.5	-	0.3	0.03	-	-
Mar/90	310	15,800	0.5	-	-	0.03	-	-
Apr/90	328	14,300	1.0	-	-	-	-	-
May/90	318	16,700	-	-	-	-	-	-
Jun/90	340	15,900	0.3	-	-	-	-	-

Values for aluminium and zink are monthly averages.

Average flow, Production and Conductivity data from Beaver Wood Fibre Company Ltd., Control point 0100 (9-5-1991).



TSS, DOC and BOD5 data from Beaver Wood Fibre Company Ltd., Control point 0100 (9-5-1991).

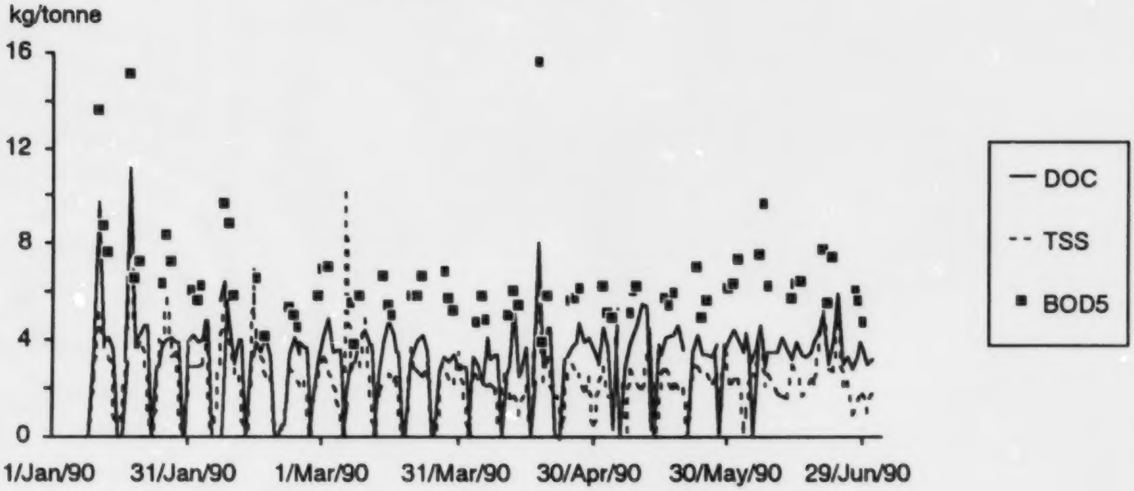


Table 1b. Halogenated volatiles (ATG16). Domtar Inc., Fine Papers Div. (St. Catharines). (Date: 29-4-1991).

Company: 0000140509

Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	Chloromethane mg/tonne	Chloroethylene mg/tonne	Bromomethane mg/tonne	Bromodichloromethane mg/tonne	Dichloromethane mg/tonne	1,1-Dichloroethane mg/tonne	1,2-Dichloroethane mg/tonne	1,1-Dichloroethylene mg/tonne
Jan-90	169	9,716	-	-	-	-	-	-	-	-
Feb-90	212	10,351	0	-	0	-	0	-	-	-
Mar-90	151	11,986	0	-	0	-	0	-	-	0
Apr-90	164	13,929	-	-	-	0	-	-	-	-
May-90	191	9,711	-	-	-	-	0	-	-	-
Jun-90	186	11,545	-	-	-	-	0	-	-	-

Company: 0000140509

Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	trans-1,2-Dichloroethylene mg/tonne	1,2-Dichloropropane mg/tonne	cis-1,3-Dichloropropylen mg/tonne	trans-1,3-Dichloropropylen mg/tonne	Dibromoethylene mg/tonne	Trichloromethane mg/tonne	Dibromochloromethane mg/tonne	Tribromomethane mg/tonne	1,1,2-Trichloroethane mg/tonne
Jan-90	169	9,716	-	-	-	-	-	0	0	-	-
Feb-90	212	10,351	-	-	-	-	-	-	-	-	-
Mar-90	151	11,986	-	-	-	-	-	0	-	-	-
Apr-90	164	13,929	-	-	-	-	-	0	0	-	-
May-90	191	9,711	-	-	-	-	-	0	-	-	-
Jun-90	186	11,545	-	-	-	-	-	-	-	-	-

Company: 0000140509

Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	Trichloroethylene mg/tonne	Trifluorochloromethane mg/tonne	Tetrachloromethane mg/tonne	1,1,2,2-Tetrachloroethane mg/tonne	Tetrachloroethylene mg/tonne	Chlorobenzene mg/tonne	1,2-Dichlorobenzene mg/tonne	1,3-Dichlorobenzene mg/tonne	1,4-Dichlorobenzene mg/tonne
Jan-90	169	9,716	0	-	-	-	-	-	-	-	-
Feb-90	212	10,351	-	0	-	-	0	-	-	-	-
Mar-90	151	11,986	-	-	-	-	-	-	-	-	-
Apr-90	164	13,929	-	-	-	-	-	-	-	-	-
May-90	191	9,711	-	-	-	-	-	-	-	-	-
Jun-90	186	11,545	-	-	-	-	-	-	-	-	-

Table 2b. Nonhalogenated volatiles (ATG17). Domtar Inc., Fine Papers Div. (St. Catharines). (Date: 29-4-1991).

Company: 0000140509

Cntr.pt: 01	Prod. T/day	Daily flow m3/day	Styrene mg/tonne	Benzene mg/tonne	m,p-Xylene mg/tonne	o-Xylene mg/tonne	Toluene mg/tonne
Date							
Jan-90	169	9,716	-	0	0	0	0
Feb-90	212	10,351	0	-	-	0	0
Mar-90	151	11,986	0	-	0	0	-
Apr-90	164	13,929	-	0	0	-	-
May-90	191	9,711	-	-	0	0	0
Jun-90	186	11,545	-	0	-	-	0

Table 9b. Inorganics (ATG 3, 4, 6, 7 & 15). Domtar Inc., Fine Papers Div. (St. Catharines). (Date: 29-4-1991).

Company: 0000140509

Cntr.pt: 01	Prod. T/day	Av. flow m3/day	pH	Conductivity µs/cm	NH3 + NH4 g/tonne	NO2+NO3 g/tonne	Total-N g/tonne	Total-P g/tonne	Sulphide g/tonne
Date									
Jan-90	169	10,366	6.5	400	3	9	227	0	-
Feb-90	179	10,758	6.4	410	7	25	44	1	-
Mar-90	159	10,265	6.5	358	5	28	174	1	-
Apr-90	166	10,962	6.9	365	3	30	78	1	-
May-90	156	9,605	6.3	354	2	19	90	1	-
Jun-90	139	10,935	6.9	376	1	36	71	3	-

Table 10b. Group and unspecific variables (ATG 1, 5, 8, PP1-3). Domtar Inc., Fine Papers Div. (St. Catharines). (Date: 29-4-1991)

Company: 0000140509

Cntr.pt.: 01	Prod. T/day	Av. flow m3/tonne	BOD5 Kg/tonne	AOX Kg/tonne	COD Kg/tonne	DOC Kg/tonne	TOC Kg/tonne	TSS Kg/tonne	VSS Kg/tonne	COD/BOD
Date										
Jan-90	169	61	5.5	-	40.0	-	-	1.5	-	7.2
Feb-90	179	60	6.8	-	216.0	-	-	3.0	-	31.9
Mar-90	159	65	4.9	-	118.4	-	-	2.1	-	24.0
Apr-90	166	66	8.7	-	51.1	-	-	1.8	-	5.9
May-90	156	62	11.0	-	68.1	0.0	-	4.6	-	6.2
Jun-90	139	79	7.0	-	37.9	-	-	2.3	-	5.4

Table 3b. Extractable base neutrals (ATG19). Domtar Inc., Fine Papers Div. (St. Catharines). (Date: 29-4-1991).

Company: 0000140509 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Naphthalene mg/tonne	1-Methyl-naphthalene mg/tonne	2-Methyl-naphthalene mg/tonne	1-Chloro-naphthalene mg/tonne	2-Chloro-naphthalene mg/tonne	Anthracene mg/tonne	Benz[a]-anthracene mg/tonne	Dibenz[a] anthracene mg/tonne
Jan-90	169	9,716	-	-	-	-	-	-	-	-
Feb-90	212	10,351	-	-	-	-	-	-	-	-
Mar-90	151	11,986	-	-	-	-	-	-	-	-
Apr-90	164	13,929	-	-	-	-	-	-	-	-
May-90	191	9,711	-	-	-	-	-	-	-	-
Jun-90	186	11,545	-	-	-	-	-	-	-	-

Company: 0000140509 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Phenan-threne mg/tonne	Acenaph-thene mg/tonne	Acenaph-thylene mg/tonne	5-Nitro-ace-naphthene mg/tonne	Chrysene mg/tonne	Fluor-anthene mg/tonne	Benz[b]-fluoranthene mg/tonne	Benz[k] fluoranthene mg/tonne	Fluorene mg/tonne
Jan-90	169	9,716	-	-	-	-	-	-	-	-	-
Feb-90	212	10,351	-	-	-	-	-	-	-	-	-
Mar-90	151	11,986	-	-	-	-	-	-	-	-	-
Apr-90	164	13,929	-	-	-	-	-	-	-	-	-
May-90	191	9,711	-	-	-	-	-	-	-	-	-
Jun-90	186	11,545	-	-	-	-	-	-	-	-	-

Company: 0000140509 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Pyrene mg/tonne	Benz[a]-pyrene mg/tonne	Indeno[1,2,3-cd pyrene mg/tonne	Perylene mg/tonne	Benz[g,h,i]-perylene mg/tonne	Indole mg/tonne	Camphene mg/tonne
Jan-90	169	9,716	-	-	-	-	-	-	0
Feb-90	212	10,351	-	-	-	-	-	-	-
Mar-90	151	11,986	-	-	-	-	-	-	-
Apr-90	164	13,929	-	-	-	-	-	-	-
May-90	191	9,711	-	-	-	-	-	-	-
Jun-90	186	11,545	-	-	-	-	-	-	-

Table 4b. Acidic extractables (ATG20). Domtar Inc., Fine Papers Div. (St. Catharines). (Date: 29-4-1991).

Company: 0000140509 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Phenol mg/tonne	m-Cresol mg/tonne	o-Cresol mg/tonne	p-Cresol mg/tonne	2,4-xylenol mg/tonne	4-Chloro-m-cresol mg/tonne	2-Chloro-phenol mg/tonne	2,4-Dichloro-phenol mg/tonne
Jan-90	169	9,716	-	-	-	-	-	-	-	-
Feb-90	212	10,351	-	-	-	-	-	-	-	-
Mar-90	151	11,986	-	-	-	-	-	-	-	-
Apr-90	164	13,929	0	-	-	-	-	-	-	-
May-90	191	9,711	0	-	-	-	-	-	-	-
Jun-90	186	11,545	0	-	-	-	-	-	-	-

Company: 0000140509 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	2,6-Dichloro-phenol mg/tonne	2,3,4-Tri-chlorophenol mg/tonne	2,3,5-Tri-chlorophenol mg/tonne	2,4,5-Tri-chlorophenol mg/tonne	2,4,6-Tri-chlorophenol mg/tonne	2,3,4,5-Tetra-chlorophenol mg/tonne	2,3,4,6-Tetra-chlorophenol mg/tonne	2,3,5,6-Tetra-chlorophenol mg/tonne	Penta-chlorophenol mg/tonne
Jan-90	169	9,716	-	-	-	-	-	-	-	-	-
Feb-90	212	10,351	-	-	-	-	-	-	-	-	-
Mar-90	151	11,986	-	-	-	-	-	-	-	-	-
Apr-90	164	13,929	-	-	-	-	-	-	-	-	-
May-90	191	9,711	-	-	-	-	-	-	-	-	-
Jun-90	186	11,545	-	-	-	-	-	-	-	-	-

Company: 0000140509 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	4-Nitro-phenol mg/tonne	2,4-Dinitro-phenol mg/tonne	4,6-Dinitro-o-cresol mg/tonne
Jan-90	169	9,716	-	-	-
Feb-90	212	10,351	-	-	-
Mar-90	151	11,986	-	-	-
Apr-90	164	13,929	-	-	-
May-90	191	9,711	-	-	-
Jun-90	186	11,545	-	-	-

Table 5b. Chlorinated, neutrals (ATG(23). Domtar Inc., Fine Papers Div. (St. Catharines). (Date: 29-4-1991).

Company: 0000140509 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Hexachloro-ethane mg/tonne	Hexachloro-butadiene mg/tonne	Hexachloro-cyclopentadien mg/tonne	1,2,3-Trichloro-benzene mg/tonne	1,2,4-Trichloro-benzene mg/tonne	2,4,5-Trichloro-toluene mg/tonne	1,2,3,4-Tetra-chlorobenzene mg/tonne	1,2,3,5-Tetra-chlorobenzene mg/tonne
Jan-90	169	9,716	-	-	-	-	0.0	0.0	0.0	-
Feb-90	212	10,351	-	-	-	-	-	-	-	-
Mar-90	151	11,986	-	-	-	-	-	0.0	-	-
Apr-90	164	13,929	-	-	-	-	-	-	-	-
May-90	191	9,711	-	-	-	-	-	-	-	-
Jun-90	186	11,545	-	-	-	-	-	-	-	-

Company: 0000140509 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	1,2,4,5-Tetra-chlorobenzene mg/tonne	Penta-chlorobenzene mg/tonne	Hexa-chlorobenzene mg/tonne	Octachloro-styrene mg/tonne
Jan-90	169	9,716	-	0.0	-	-
Feb-90	212	10,351	-	-	-	-
Mar-90	151	11,986	-	-	-	-
Apr-90	164	13,929	-	-	-	-
May-90	191	9,711	-	-	-	-
Jun-90	186	11,545	-	-	-	-

Table 6b. Chlorinated dioxins, dibenzofuranes and PCB's (ATG(23). Domtar Inc., Fine Papers Div. (St. Catharines). (Date: 29-4-1991).

Company: 0000140509 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	2,3,7,8-TCDD µgtonne	Total TCDD µgtonne	Total TCDF µgtonne	Total PCDD µgtonne	Total PCDF µgtonne	Total HxCDD µgtonne	Total HxCDF µgtonne	Total HpCDD µgtonne
Apr-90	192	11,518	-	-	-	-	-	-	-	-
Jun-90	116	12,957	-	-	-	-	-	-	-	-
	-		-	-	-	-	-	-	-	-
	-		-	-	-	-	-	-	-	-
	-		-	-	-	-	-	-	-	-
	-		-	-	-	-	-	-	-	-

Company: 0000140509 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Total HpCDF µg/tonne	OCDD µg/tonne	OCDF µg/tonne	Total PCB's µg/tonne
Apr-90	192	11,518	-	-	-	-
Jun-90	116	12,957	-	0.0	-	-
	-		-	-	-	-
	-		-	-	-	-
	-		-	-	-	-
	-		-	-	-	-

Table 7b. Fatty and resin acids (ATG 26). Domtar Inc., Fine Papers Div. (St. Catharines). (Date: 29-4-1991).

Company: 0000140509 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Oleic acid g/tonne	Pimaric acid g/tonne	Abietic acid g/tonne	Dehydro-abietic acid g/tonne	Isopimaric acid g/tonne	Levopimaric acid g/tonne	Neoabietic acid g/tonne	Chlorodehydro-abietic acid g/tonne
Jan-90	169	9,716	-	-	0.0	41.7	-	-	-	-
Feb-90	212	10,351	-	-	0.0	44.1	0.0	-	-	-
Mar-90	151	11,986	-	0.0	0.0	183.5	0.0	0.0	-	0.0
Apr-90	164	13,929	-	0.0	0.0	40.1	0.0	-	-	0.0
May-90	191	9,711	-	-	0.0	30.2	0.0	0.0	-	-
Jun-90	186	11,545	-	-	0.0	15.9	0.0	-	-	-

Company: 0000140509 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Dichlorodehydro-abietic acid g/tonne	Total resin acids g/tonne	Total resin acids Kg/day	Total resin acids <mg/l>
Jan-90	169	9,716	-	41.7	7	0.73
Feb-90	212	10,351	-	44.1	9	0.90
Mar-90	151	11,986	-	183.5	28	2.31
Apr-90	164	13,929	-	40.1	7	0.47
May-90	191	9,711	-	30.2	6	0.59
Jun-90	186	11,545	-	15.9	3	0.26

Values for dehydroabietic acid and dichlorodehydroabietic acid are monthly averages

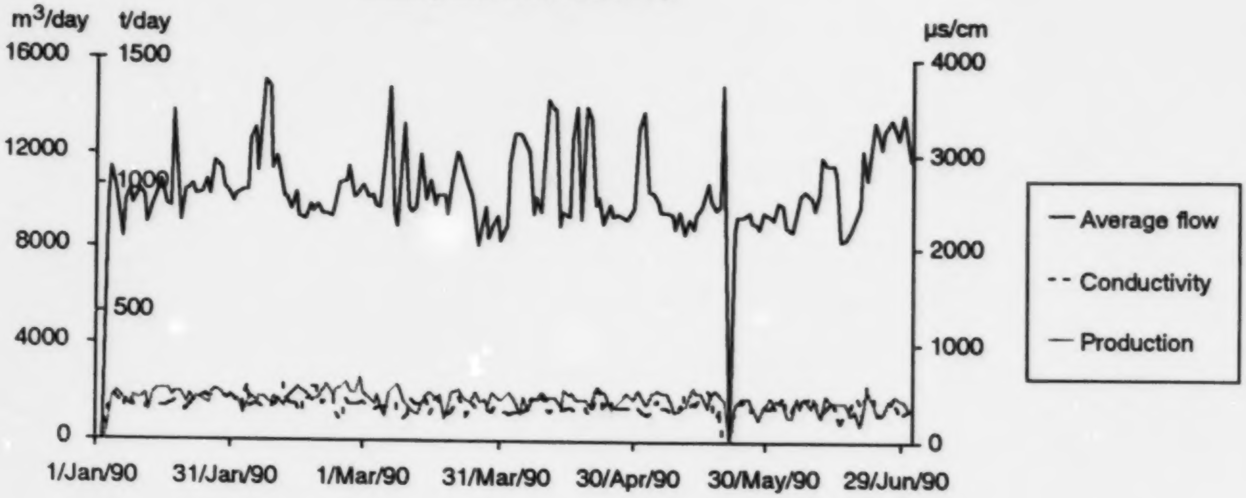
Table 8b. Metals (ATG 9 &12). Domtar Inc., Fine Papers Div. (St. Catharines). (Date: 29-4-1991).

Company 00001405C	Prod. T/day	Daily flow m3/day	Berylium g/tonne	Aluminium g/tonne	Copper g/tonne	Zinc g/tonne	Chromium g/tonne	Nickel g/tonne	Molybdenum g/tonne	Cobalt g/tonne
Date										
Jan-90	169	9,716	-	112	0.0	1.2	0.0	-	-	-
Feb-90	212	10,351	-	108	0.0	1.2	-	-	-	-
Mar-90	151	11,986	-	138	0.0	1.2	0.0	-	-	-
Apr-90	164	13,929	-	184	-	0.6	-	-	0.0	-
May-90	191	9,711	-	73	-	0.7	0.0	0.0	-	-
Jun-90	186	11,545	-	69	0.0	0.6	0.0	-	-	-

Company 00001405C	Prod. T/day	Daily flow m3/day	Vanadium g/tonne	Silver g/tonne	Lead g/tonne	Cadmium g/tonne	Thallium g/tonne	Mercury g/tonne
Date								
Jan-90	169	9,716	0.0	-	0.0	0.00	-	-
Feb-90	212	10,351	0.0	-	-	0.00	-	-
Mar-90	151	11,986	0.0	-	-	0.00	-	-
Apr-90	164	13,929	0.0	-	-	-	-	-
May-90	191	9,711	0.0	-	0.0	0.00	-	-
Jun-90	186	11,545	-	-	-	-	-	-

Values for aluminium and zink are monthly averages.

Average flow, Production and Conductivity data from Domtar Inc., Fine Papers Division (St. Catharines), Control point 0100 (14-5-1991).



TSS, COD and BOD5 data from Domtar Inc., Fine Papers Division (St Catharines), Control point 0100 (14-5-1991).

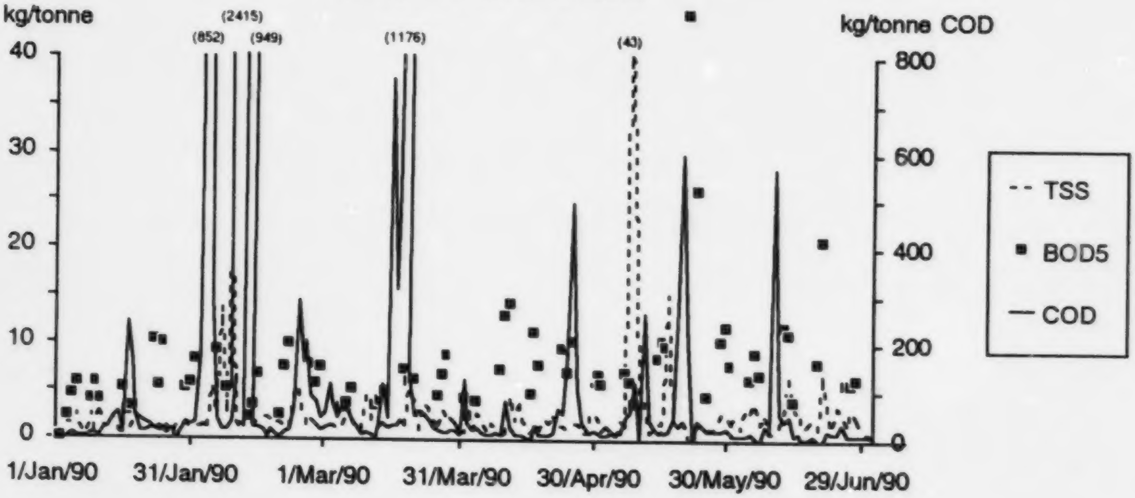


Table 1b. Halogenated volatiles (ATG16). E.B. Eddy Forest Products Ltd. (Ottawa). (Date: 29-4-1991).

Company: 0000980201 Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	Chloro-methane mg/tonne	Chloro-ethylene mg/tonne	Bromo-methane mg/tonne	Bromodi-chloromethane mg/tonne	Dichloro-methane mg/tonne	1,1-Dichloro-ethane mg/tonne	1,2-Dichloro-ethane mg/tonne	1,1-Dichloro-ethylene mg/tonne
Jan/90	187	9,523	-	-	-	-	86	-	-	-
Feb/90	170	8,493	-	-	655	-	-	-	-	-
Mar/90	198	8,264	-	-	-	-	-	-	-	-
Apr/90	244	7,480	67	-	95	-	-	-	-	-
Jun/90	185	6,647	-	-	72	-	-	-	-	-

Company: 0000980201 Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	trans-1,2-Di-chloroethylene mg/tonne	1,2-Dichloro-propane mg/tonne	cis-1,3-Di-chloropropylene mg/tonne	trans-1,3-Di-chloropropylene mg/tonne	Dibromo-ethylene mg/tonne	Trichloro-methane mg/tonne	Dibromo-chloromethane mg/tonne	Tribromo-methane mg/tonne	1,1,2-Tri-chloroethane mg/tonne
Jan/90	187	9,523	-	-	-	-	-	358	-	-	-
Feb/90	170	8,493	-	-	-	-	-	95	-	-	-
Mar/90	198	8,264	-	-	-	-	-	138	-	-	-
Apr/90	244	7,480	-	-	-	-	-	86	-	-	-
Jun/90	185	6,647	-	-	-	-	-	75	-	-	0

Company: 0000980201 Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	Trichloro-ethylene mg/tonne	Trifluoro-chloromethane mg/tonne	Tetrachloro-methane mg/tonne	1,1,2,2-Tetra-chloroethane mg/tonne	Tetrachloro-ethylene mg/tonne	Chloro-benzene mg/tonne	1,2-Dichloro-benzene mg/tonne	1,3-Dichloro-benzene mg/tonne	1,4-Dichloro-benzene mg/tonne
Jan/90	187	9,523	-	-	-	-	-	-	-	-	-
Feb/90	170	8,493	-	-	-	-	-	-	-	-	-
Mar/90	198	8,264	-	-	-	-	-	-	-	-	-
Apr/90	244	7,480	-	-	-	-	-	-	-	-	-
Jun/90	185	6,647	-	-	-	-	-	-	-	-	-

Table 2b. Nonhalogenated volatiles (ATG17). E.B. Eddy Forest Products Ltd. (Ottawa). (Date: 29-4-1991).

Company: 0000980201 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Styrene mg/tonne	Benzene mg/tonne	m,p-Xylene mg/tonne	o-Xylene mg/tonne	Toluene mg/tonne
Jan/90	187	9,523	-	57	-	-	-
Feb/90	170	8,493	-	-	40	30	62
Mar/90	198	8,264	-	-	-	-	17
Apr/90	244	7,480	-	12	17	8	-
Jun/90	185	6,647	-	144	61	22	-

Table 9b. Inorganics (ATG 3, 4, 6, 7 & 15). E.B. Eddy Forest Products Ltd. (Ottawa). (Date: 29-4-1991).

Company: 0000980201 Cntr.pt.: 01 Date	Prod. T/day	Av. flow m3/day	pH	Conductivity µs/cm	NH3 + NH4 g/tonne	NO2+NO3 g/tonne	Total-N g/tonne	Total-P g/tonne	Sulphide g/tonne
Jan/90	189	8,465	7.7	323	11	18	130	1	-
Feb/90	164	8,032	6.8	311	14	13	499	19	-
Mar/90	160	7,271	7.7	365	15	12	59	3	-
Apr/90	209	6,671	6.9	341	9	8	54	1	-
May/90	140	5,339	5.5	290	-	-	-	-	-
Jun/90	133	4,836	4.9	227	9	8	94	2	-

Table 10b. Group and unspecific variables (ATG 1, 5, 8, PP1-3). E.B. Eddy Forest Products Ltd. (Ottawa). (Date: 29-4-1991).

Company: 0000980201 Cntr.pt.: 01 Date	Prod. T/day	Av. flow m3/tonne	BOD5 Kg/tonne	AOX Kg/tonne	COD Kg/tonne	DOC Kg/tonne	TOC Kg/tonne	TSS Kg/tonne	VSS Kg/tonne	COD/BOD
Jan/90	189	45	0.3	-	18.0	0.0	-	3.4	-	52
Feb/90	164	49	0.3	-	18.9	-	-	3.7	-	57
Mar/90	160	45	0.3	-	15.3	-	-	3.4	-	44
Apr/90	209	32	0.2	-	10.7	-	-	2.5	-	49
May/90	140	38	0.2	-	11.6	-	-	2.0	-	55
Jun/90	133	36	0.2	-	8.5	-	-	1.5	-	48

Table 3b. Extractable base neutrals (ATG19). E.B. Eddy Forest Products Ltd. (Ottawa). (Date: 29-4-1991).

Company: 0000980201
Cntr pt.: 01

Date	Prod. T/day	Daily flow m3/day	Naphthalene mg/tonne	1-Methyl-naphthalene mg/tonne	2-Methyl-naphthalene mg/tonne	1-Chloro-naphthalene mg/tonne	2-Chloro-naphthalene mg/tonne	Anthracene mg/tonne	Benz[a]-anthracene mg/tonne	Dibenz[a] anthracene mg/tonne
Jan/90	187	9,523	167	-	-	-	-	-	-	-
Feb/90	170	8,493	-	-	-	-	-	-	-	-
Mar/90	198	8,264	81	-	-	-	-	-	-	-
Apr/90	244	7,480	162	-	-	-	-	-	-	-
Jun/90	185	6,647	137	-	-	-	-	-	-	-

Company: 0000980201
Cntr pt.: 01

Date	Prod. T/day	Daily flow m3/day	Phenanthrene mg/tonne	Acenaphthene mg/tonne	Acenaphthylene mg/tonne	5-Nitro-acenaphthene mg/tonne	Chrysene mg/tonne	Fluoranthene mg/tonne	Benz[b]-fluoranthene mg/tonne	Benz[k] fluoranthene mg/tonne	Fluorene mg/tonne
Jan/90	187	9,523	-	-	-	-	-	-	-	-	-
Feb/90	170	8,493	-	-	-	-	-	-	-	-	-
Mar/90	198	8,264	-	-	-	-	-	-	-	-	-
Apr/90	244	7,480	-	-	-	-	-	-	-	-	-
Jun/90	185	6,647	-	-	-	-	-	-	-	-	-

Company: 0000980201
Cntr pt.: 01

Date	Prod. T/day	Daily flow m3/day	Pyrene mg/tonne	Benz[a]-pyrene mg/tonne	Ideno[1,2,3-cd pyrene mg/tonne	Perylene mg/tonne	Benz[g,h,i]-perylene mg/tonne	Indole mg/tonne	Camphene mg/tonne
Jan/90	187	9,523	-	-	-	-	-	-	-
Feb/90	170	8,493	-	-	-	-	-	-	-
Mar/90	198	8,264	-	-	-	-	-	-	-
Apr/90	244	7,480	-	-	-	-	-	-	-
Jun/90	185	6,647	-	-	-	-	-	-	-

Table 4b. Acidic extractables (ATG20). E.B. Eddy Forest Products Ltd. (Ottawa). (Date: 29-4-1991).

Company: 0000980201
Cntr pt.: 01

Date	Prod. T/day	Daily flow m3/day	Phenol mg/tonne	m-Cresol mg/tonne	o-Cresol mg/tonne	p-Cresol mg/tonne	2,4-xylenol mg/tonne	4-Chloro-m-cresol mg/tonne	2-Chloro-phenol mg/tonne	2,4-Dichloro-phenol mg/tonne
Jan/90	187	9,523	-	-	-	-	-	-	-	-
Feb/90	170	8,493	-	-	-	-	-	-	-	-
Mar/90	198	8,264	-	-	-	-	-	-	-	-
Apr/90	244	7,480	21	18	-	-	-	-	-	-
Jun/90	185	6,647	50	65	-	29	-	-	-	-

Company: 0000980201
Cntr pt.: 01

Date	Prod. T/day	Daily flow m3/day	2,6-Dichloro-phenol mg/tonne	2,3,4-Tri-chlorophenol mg/tonne	2,3,5-Tri-chlorophenol mg/tonne	2,4,5-Tri-chlorophenol mg/tonne	2,4,6-Tri-chlorophenol mg/tonne	2,3,4,5-Tetra-chlorophenol mg/tonne	2,3,4,6-Tetra-chlorophenol mg/tonne	2,3,5,6-Tetra-chlorophenol mg/tonne	Penta-chlorophenol mg/tonne
Jan/90	187	9,523	-	-	-	-	-	-	-	-	-
Feb/90	170	8,493	-	-	-	-	-	-	-	-	-
Mar/90	198	8,264	-	-	-	-	-	-	-	-	-
Apr/90	244	7,480	-	-	-	-	-	-	-	-	-
Jun/90	185	6,647	-	-	-	-	-	-	-	-	0

Company: 0000980201
Cntr pt.: 01

Date	Prod. T/day	Daily flow m3/day	4-Nitro-phenol mg/tonne	2,4-Dinitro-phenol mg/tonne	4,6-Dinitro-o-cresol mg/tonne
Jan/90	187	9,523	-	-	-
Feb/90	170	8,493	-	-	-
Mar/90	198	8,264	-	-	-
Apr/90	244	7,480	-	-	-
Jun/90	185	6,647	-	-	-

Table 5b. Chlorinated, neutrals (ATG(23). E.B. Eddy Forest Products Ltd. (Ottawa). (Date: 29-4-1991).

Company 0000980201 Cntr pt 01	Prod T/day	Daily flow m3/day	Hexachloroethane mg/tonne	Hexachlorobutadiene mg/tonne	Hexachlorocyclopentadien mg/tonne	1,2,3-Trichlorobenzene mg/tonne	1,2,4-Trichlorobenzene mg/tonne	2,4,5-Trichlorotoluene mg/tonne	1,2,3,4-Tetrachlorobenzene mg/tonne	1,2,3,5-Tetrachlorobenzene mg/tonne
Date										
Jan/90	187	9,523	-	-	-	0.4	1.2	-	0.4	-
Feb/90	170	8,493	-	-	-	0.5	1.7	-	0.3	-
Mar/90	198	8,264	-	-	1.0	0.3	1.9	-	-	-
Apr/90	244	7,480	-	-	-	0.4	1.7	-	0.6	-
Jun/90	185	6,647	-	-	-	0.3	0.1	-	0.5	-

Company 0000980201 Cntr pt 01	Prod T/day	Daily flow m3/day	1,2,4,5-Tetrachlorobenzene mg/tonne	Pentachlorobenzene mg/tonne	Hexachlorobenzene mg/tonne	Octachlorostyrene mg/tonne
Date						
Jan/90	187	9,523	-	-	-	-
Feb/90	170	8,493	-	-	-	-
Mar/90	198	8,264	-	-	-	-
Apr/90	244	7,480	-	-	-	-
Jun/90	185	6,647	-	-	-	-

Table 6b. Chlorinated dioxins, dibenzofuranes and PCB's (ATG(23). E.B. Eddy Forest Products Ltd. (Ottawa). (Date: 29-4-1991).

Company 0000980201 Cntr pt 01	Prod T/day	Daily flow m3/day	2,3,7,8-TCDD µgtonne	Total TCDD µgtonne	Total TCDF µgtonne	Total PCDD µgtonne	Total PCDF µgtonne	Total HxCDD µgtonne	Total HxCDF µgtonne	Total HpCDD µgtonne
Date										
Jan/90	171	9,504	-	-	-	-	-	-	-	-
Mar/90	151	6,416	-	-	-	-	-	-	-	-

Company 0000980201 Cntr pt 01	Prod T/day	Daily flow m3/day	Total HpCDF µg/tonne	OCDD µg/tonne	OCDF µg/tonne	Total PCB's µg/tonne
Date						
Jan/90	171	9,504	-	-	-	-
Mar/90	151	6,416	-	4.2	-	-

Table 7b. Fatty and resin acids (ATG 26). E.B. Eddy Forest Products Ltd. (Ottawa). (Date: 29-4-1991).

Company 0000980201 Cntr pt 01	Prod T/day	Daily flow m3/day	Oleic acid g/tonne	Pimaric acid g/tonne	Abietic acid g/tonne	Dehydroabietic acid g/tonne	Isopimaric acid g/tonne	Levopimaric acid g/tonne	Neoabietic acid g/tonne	Chlorodehydroabietic acid g/tonne
Date										
Jan/90	187	9,523	-	-	1.4	4.6	0.4	-	-	-
Feb/90	170	8,493	-	0.7	2.5	14.4	1.4	-	-	-
Mar/90	198	8,264	-	-	12.9	31.2	-	3.1	-	-
Jun/90	185	6,647	-	0.4	0.3	-	0.7	1.3	-	-

Company 0000980201 Cntr pt 01	Prod T/day	Daily flow m3/day	Dichlorodehydroabietic acid g/tonne	Total resin acids g/tonne	Total resin acids Kg/day	Total resin acids <mg/l>
Date						
Jan/90	187	9,523	-	6.4	1	0.13
Feb/90	170	8,493	-	19.0	3	0.38
Mar/90	198	8,264	-	47.2	9	1.13
Jun/90	185	6,647	-	2.7	1	0.08

Values for dehydroabietic acid and dichlorodehydroabietic acid are monthly averages

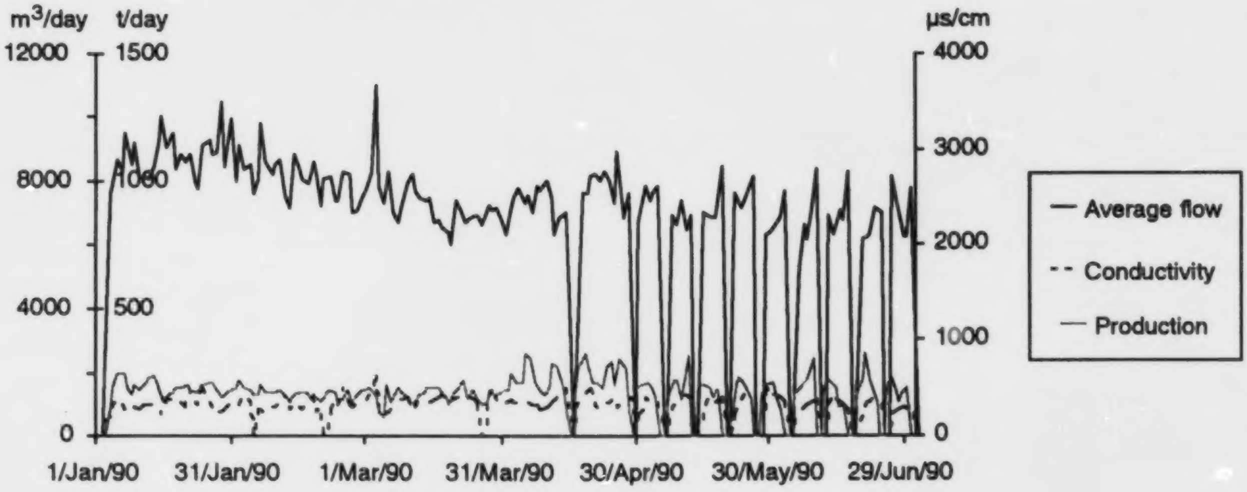
Table 8b. Metals (ATG 9 &12). E.B. Eddy Forest Products Ltd. (Ottawa). (Date: 29-4-1991).

Company 00009802C	Prod. T/day	Daily flow m3/day	Berylium g/tonne	Aluminium g/tonne	Copper g/tonne	Zinc g/tonne	Chromium g/tonne	Nickel g/tonne	Molybdenum g/tonne	Cobalt g/tonne
Date										
Jan/90	187	9,523	-	113	0.7	0.5	-	0.3	-	-
Feb/90	170	8,493	-	141	-	1.2	-	-	-	-
Mar/90	198	8,264	-	104	0.5	0.4	-	0.3	-	-
Apr/90	244	7,480	-	85	0.2	0.2	-	-	-	-
Jun/90	185	6,647	-	-	-	-	-	-	-	-

Company 00009802C	Prod. T/day	Daily flow m3/day	Vanadium g/tonne	Silver g/tonne	Lead g/tonne	Cadmium g/tonne	Thallium g/tonne	Mercury g/tonne
Date								
Jan/90	187	9,523	-	-	0.1	0.02	-	-
Feb/90	170	8,493	-	-	0.3	0.03	-	-
Mar/90	198	8,264	-	-	-	0.03	-	0.01
Apr/90	244	7,480	-	-	-	-	-	-
Jun/90	185	6,647	-	-	-	-	-	-

Values for aluminium and zink are monthly averages

Average flow, Production and Conductivity data from E.B. Eddy Forest Products Ltd. (Ottawa), Control point 0100 (14-5-1991).



TSS, COD and BOD5 data from E.B. Eddy Forest Products Ltd. (Ottawa), Control point 0100 (14-5-1991).

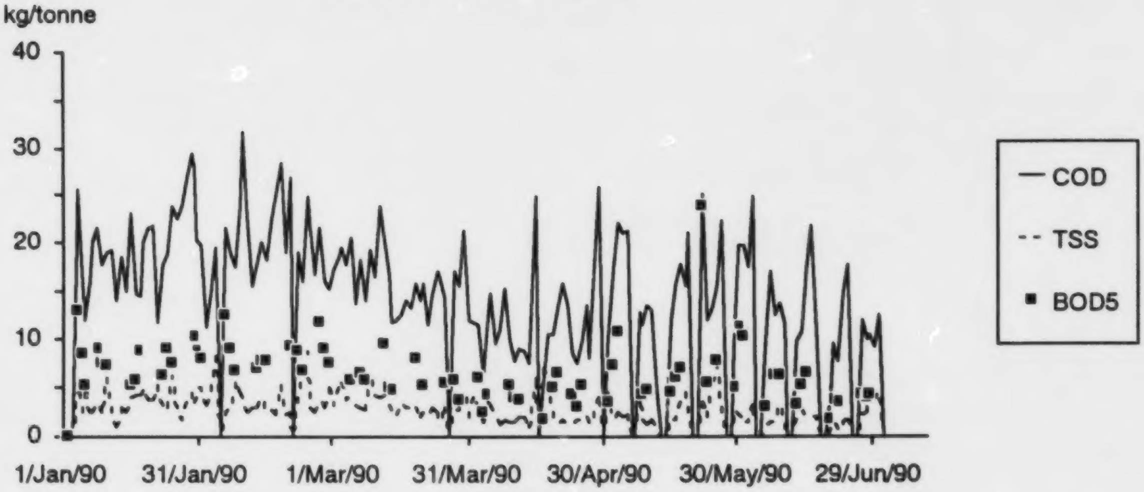


Table 1b. Halogenated volatiles (ATG16). Noranda Forest Inc., Recycled Papers. (Date: 2-5-1991).

Company: 0000940007

	Cntr.pt.: 01 Prod. T/day	Daily flow m3/day	Chloro-methane mg/tonne	Chloro-ethylene mg/tonne	Bromo-methane mg/tonne	Bromodi-chloromethane mg/tonne	Dichloro-methane mg/tonne	1,1-Dichloro-ethane mg/tonne	1,2-Dichloro-ethane mg/tonne	1,1-Dichloro-ethylene mg/tonne
Jan/90	269	19,129	-	-	288	413	-	-	-	-
Feb/90	284	21,188	71	-	-	279	-	-	-	139
Mar/90	255	19,140	-	-	225	307	820	-	-	-
Apr/90	267	22,443	-	-	-	517	87	-	-	-
May/90	274	22,661	-	-	-	231	-	-	-	-

Company: 0000940007

	Cntr.pt.: 01 Prod. T/day	Daily flow m3/day	trans-1,2-Di-chloroethylene mg/tonne	1,2-Dichloro-propane mg/tonne	cis-1,3-Di-chloropropylene mg/tonne	trans-1,3-Di-chloropropylene mg/tonne	Dibromo-ethylene mg/tonne	Trichloro-methane mg/tonne	Dibromo-chloromethane mg/tonne	Tribromo-methane mg/tonne	1,1,2-Tri-chloroethane mg/tonne
Jan/90	269	19,129	-	-	-	-	-	5,765	83	-	-
Feb/90	284	21,188	-	-	-	-	-	4,382	58	-	-
Mar/90	255	19,140	-	-	-	-	-	4,008	77	-	-
Apr/90	267	22,443	-	-	-	-	-	15,837	77	-	-
May/90	274	22,661	-	-	-	-	-	4,924	-	-	-

Company: 0000940007

	Cntr.pt.: 01 Prod. T/day	Daily flow m3/day	Trichloro-ethylene mg/tonne	Trifluoro-chloromethane mg/tonne	Tetrachloro-methane mg/tonne	1,1,2,2-Tetra-chloroethane mg/tonne	Tetrachloro-ethylene mg/tonne	Chloro-benzene mg/tonne	1,2-Dichloro-benzene mg/tonne	1,3-Dichloro-benzene mg/tonne	1,4-Dichloro-benzene mg/tonne
Jan/90	269	19,129	-	-	-	-	-	-	-	-	-
Feb/90	284	21,188	-	-	-	-	-	-	-	-	-
Mar/90	255	19,140	-	-	-	-	-	-	-	-	-
Apr/90	267	22,443	-	-	-	-	-	23	-	-	-
May/90	274	22,661	-	-	-	-	-	-	-	-	-

Table 2b. Nonhalogenated volatiles (ATG17). Noranda Forest Inc., Recycled Papers. (Date: 2-5-1991).

Company: 0000940007

Date	Cntr.pt.: 01 Prod. T/day	Daily flow m3/day	Styrene mg/tonne	Benzene mg/tonne	m,p-Xylene mg/tonne	o-Xylene mg/tonne	Toluene mg/tonne
Jan/90	269	19,129	48	452	105	56	21
Feb/90	284	21,188	-	-	384	202	21
Mar/90	255	19,140	-	-	71	74	-
Apr/90	267	22,443	21	183	533	192	-
May/90	274	22,661	-	-	77	-	-

Table 9b. Inorganics (ATG 3, 4, 6, 7 & 15). Noranda Forest Inc., Recycled Papers. (Date: 2-5-1991).

Company: 0000940007

Date	Cntr.pt.: 01 Prod. T/day	Av. flow m3/day	pH	Conductivity µs/cm	NH3 + NH4 g/tonne	NO2+NO3 g/tonne	Total-N g/tonne	Total-P g/tonne	Sulphide g/tonne
Jan/90	269	20,716		899	13	35	96	5	-
Feb/90	284	20,963		896	7	40	94	6	-
Mar/90	255	21,118		907	5	57	60	6	-
Apr/90	267	21,206		893	21	64	148	13	-
May/90	274	20,404		899	10	45	103	-	-
Jun/90	271	22,989		938	18	55	184	16	-

Table 10b. Group and unspecific variables (ATG 1, 5, 8, PP1-3). Noranda Forest Inc., Recycled Papers. (Date: 2-5-1991).

Company: 0000940007

Date	Cntr.pt.: 01 Prod. T/day	Av. flow m3/tonne	BOD5 Kg/tonne	AOX Kg/tonne	COD Kg/tonne	DOC Kg/tonne	TOC Kg/tonne	TSS Kg/tonne	VSS Kg/tonne	DOC/AOX	DOC/BOD
Jan/90	269	77	7.9	0.1	-	5.5	-	-	-	37	0.69
Feb/90	284	74	7.2	0.1	-	6.3	-	-	-	43	0.87
Mar/90	255	83	13.7	0.1	-	7.1	-	-	-	69	0.52
Apr/90	267	79	14.8	0.2	-	6.1	-	-	-	31	0.41
May/90	274	75	12.2	1.5	-	6.3	-	-	-	4	0.51
Jun/90	271	85	15.6	-	-	8.3	-	-	-	-	0.53

Table 3b. Extractable base neutrals (ATG19). Noranda Forest Inc., Recycled Papers. (Date: 2-5-1991).

Company: 0000940007 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Naphthalene mg/tonne	1-Methyl-naphthalene mg/tonne	2-Methyl-naphthalene mg/tonne	1-Chloro-naphthalene mg/tonne	2-Chloro-naphthalene mg/tonne	Anthracene mg/tonne	Benz[a]-anthracene mg/tonne	Dibenz[a] anthracene mg/tonne
Jan/90	269	19,129	-	-	-	-	-	-	-	-
Feb/90	284	21,188	-	-	-	-	-	-	-	-
Mar/90	255	19,140	-	-	-	-	-	-	-	-
Apr/90	267	22,443	-	-	-	-	-	-	-	-
May/90	274	22,661	-	-	-	-	-	-	-	-

Company: 0000940007 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Phenan-threne mg/tonne	Acenaph-thene mg/tonne	Acenaph-thylene mg/tonne	5-Nitro-ace-naphthene mg/tonne	Chrysene mg/tonne	Fluor-anthene mg/tonne	Benz[b]-fluoranthene mg/tonne	Benz[k] fluoranthene mg/tonne	Fluorene mg/tonne
Jan/90	269	19,129	-	-	-	-	-	-	-	-	-
Feb/90	284	21,188	-	-	-	-	-	-	-	-	-
Mar/90	255	19,140	-	-	-	-	-	-	-	-	-
Apr/90	267	22,443	116	-	-	-	-	-	-	-	-
May/90	274	22,661	83	-	-	-	-	-	-	-	123

Company: 0000940007 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Pyrene mg/tonne	Benz[a]-pyrene mg/tonne	ideno[1,2,3-cd pyrene mg/tonne	Perylene mg/tonne	Benz[g,h,i]-perylene mg/tonne	Indole mg/tonne	Camphene mg/tonne
Jan/90	269	19,129	-	-	-	-	-	-	-
Feb/90	284	21,188	-	-	-	-	-	-	-
Mar/90	255	19,140	-	-	-	-	-	-	-
Apr/90	267	22,443	-	-	-	-	-	-	-
May/90	274	22,661	-	-	-	-	-	-	-

Table 4b. Acidic extractables (ATG20). Noranda Forest Inc., Recycled Papers. (Date: 2-5-1991).

Company: 0000940007 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Phenol mg/tonne	m-Cresol mg/tonne	o-Cresol mg/tonne	p-Cresol mg/tonne	2,4-xylenol mg/tonne	4-Chloro-m-cresol mg/tonne	2-Chloro-phenol mg/tonne	2,4-Dichloro-phenol mg/tonne
Jan/90	269	19,129	-	-	-	-	-	-	-	-
Feb/90	284	21,188	-	-	-	-	-	-	-	-
Mar/90	255	19,140	0	-	-	-	-	-	-	-
Apr/90	267	22,443	-	-	-	-	-	-	-	-
May/90	274	24,118	-	0	-	-	-	-	-	-

Company: 0000940007 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	2,6-Dichloro-phenol mg/tonne	2,3,4-Tri-chlorophenol mg/tonne	2,3,5-Tri-chlorophenol mg/tonne	2,4,5-Tri-chlorophenol mg/tonne	2,4,6-Tri-chlorophenol mg/tonne	2,3,4,5-Tetra-chlorophenol mg/tonne	2,3,4,6-Tetra-chlorophenol mg/tonne	2,3,5,6-Tetra-chlorophenol mg/tonne	Penta-chlorophenol mg/tonne
Jan/90	269	19,129	-	-	-	-	-	-	-	-	-
Feb/90	284	21,188	-	-	-	-	-	-	-	-	-
Mar/90	255	19,140	-	-	-	-	-	-	-	-	-
Apr/90	267	22,443	-	-	-	-	0	-	-	-	-
May/90	274	24,118	-	-	-	-	-	-	-	-	-

Company: 0000940007 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	4-Nitro-phenol mg/tonne	2,4-Dinitro-phenol mg/tonne	4,6-Dinitro-o-cresol mg/tonne
Jan/90	269	19,129	-	-	-
Feb/90	284	21,188	-	-	-
Mar/90	255	19,140	-	-	-
Apr/90	267	22,443	-	-	-
May/90	274	24,118	-	-	-

Table 5b. Chlorinated, neutrals (ATG(23). Noranda Forest Inc., Recycled Papers. (Date: 2-5-1991).

Company: 0000940007 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Hexachloro-ethane mg/tonne	Hexachloro-butadiene mg/tonne	Hexachloro-cyclopentadien mg/tonne	1,2,3-Trichloro-benzene mg/tonne	1,2,4-Trichloro-benzene mg/tonne	2,4,5-Trichloro-toluene mg/tonne	1,2,3,4-Tetra-chlorobenzene mg/tonne	1,2,3,5-Tetra-chlorobenzene mg/tonne
Jan/90	269	19,129	-	-	11.6	0.1	0.5	-	-	-
Feb/90	284	21,188	-	-	10.6	0.1	0.4	-	-	-
Mar/90	255	19,140	-	-	6.1	-	-	-	-	-
Apr/90	267	22,443	-	-	25.7	-	0.2	1.0	-	-
May/90	274	22,661	0.2	-	31.3	-	-	0.3	-	-

Company: 0000940007 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	1,2,4,5-Tetra-chlorobenzene mg/tonne	Penta-chlorobenzene mg/tonne	Hexa-chlorobenzene mg/tonne	Octachloro-styrene mg/tonne
Jan/90	269	19,129	-	-	-	-
Feb/90	284	21,188	-	-	-	-
Mar/90	255	19,140	-	-	-	-
Apr/90	267	22,443	-	-	-	-
May/90	274	22,661	-	-	-	-

Table 6b. Chlorinated dioxins, dibenzofuranes and PCB's (ATG(23). Noranda Forest Inc., Recycled Papers. (Date: 2-5-1991).

Company: 0000940007 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	2,3,7,8-TCDD µgtonne	Total TCDD µgtonne	Total TCDF µgtonne	Total PCDD µgtonne	Total PCDF µgtonne	Total HxCDD µgtonne	Total HxCDF µgtonne	Total HpCDD µgtonne
Jan/90	269	18,286	0.0	-	-	-	-	-	-	-
Feb/90	284	19,837	-	-	-	-	-	-	-	-
Mar/90	255	19,140	-	-	-	-	-	-	-	-
Apr/90	267	22,443	-	-	-	-	-	-	-	5.1
May/90	274	22,661	-	-	-	-	-	-	-	-

Company: 0000940007 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Total HpCDF µg/tonne	OCDD µg/tonne	OCDF µg/tonne	Total PCB's µg/tonne
Jan/90	269	18,286	-	-	-	-
Feb/90	284	19,837	-	5.1	-	-
Mar/90	255	19,140	-	-	-	-
Apr/90	267	22,443	-	30.8	-	-
May/90	274	22,661	-	0.0	-	-

Table 7b. Fatty and resin acids (ATG 26). Noranda Forest Inc., Recycled Papers. (Date: 2-5-1991).

Company: 0000940007 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Oleic acid g/tonne	Pimaric acid g/tonne	Abietic acid g/tonne	Dehydro-abietic acid g/tonne	Isopimaric acid g/tonne	Levopimaric acid g/tonne	Neoabietic acid g/tonne	Chlorodehydro-abietic acid g/tonne
Jan/90	269	19,129	-	-	-	30.8	-	-	-	-
Feb/90	284	21,188	-	-	-	22.1	-	-	-	-
Mar/90	255	19,140	-	-	-	39.0	-	-	-	-
Apr/90	267	22,443	-	-	-	50.8	-	-	-	-
May/90	274	22,661	1.2	-	-	48.4	-	-	-	-

Company: 0000940007 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Dichlorodehydro-abietic acid g/tonne	Total resin acids g/tonne	Total resin acids Kg/day	Total resin acids <mg/l>
Jan/90	269	19,129	-	30.8	8.3	0.4
Feb/90	284	21,188	-	22.1	6.3	0.3
Mar/90	255	19,140	-	39.0	9.9	0.5
Apr/90	267	22,443	-	50.8	13.6	0.6
May/90	274	22,661	-	48.4	13.3	0.6

Values for dehydroabietic acid and dichlorodehydroabietic acid are monthly averages

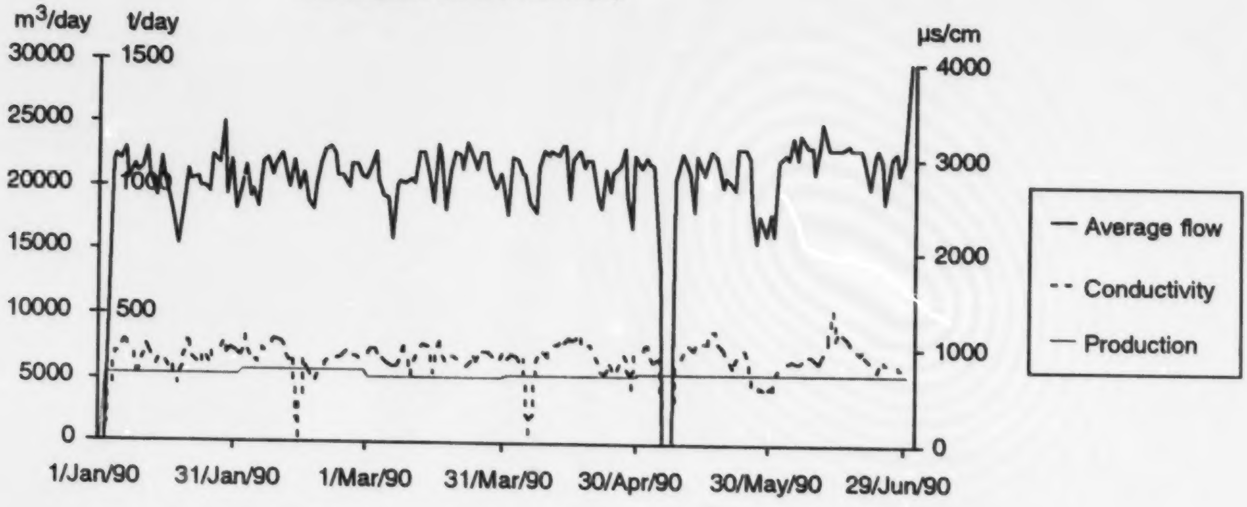
Table 8b. Metals (ATG 9 &12). Noranda Forest Inc., Recycled Papers. (Date: 2-5-1991).

Company 00009400C Date	Prod. T/day	Daily flow m3/day	Berylium g/tonne	Aluminium g/tonne	Copper g/tonne	Zinc g/tonne	Chromium g/tonne	Nickel g/tonne	Molybdenum g/tonne	Cobalt g/tonne
Jan/90	269	19,129	-	384	1.0	4.1	1.2	0.5	-	-
Feb/90	284	21,188	-	447	0.7	8.9	1.0	0.5	-	-
Mar/90	255	19,140	-	504	1.0	6.0	1.9	0.6	-	-
Apr/90	267	22,443	-	674	2.3	6.8	-	-	-	-
May/90	274	22,661	-	166	-	4.9	1.2	0.3	0.4	0.6
Jun/90	271	22,428	1.65	494	1.7	13.0	15.0	0.7	0.7	-

Company 00009400C Date	Prod. T/day	Daily flow m3/day	Vanadium g/tonne	Silver g/tonne	Lead g/tonne	Cadmium g/tonne	Thallium g/tonne	Mercury g/tonne
Jan/90	269	19,129	0.7	-	0.3	0.03	-	-
Feb/90	284	21,188	0.5	-	0.1	0.05	-	-
Mar/90	255	19,140	0.8	-	0.2	0.03	-	-
Apr/90	267	22,443	-	-	-	-	-	0.01
May/90	274	22,661	-	-	1.5	0.23	-	0.01
Jun/90	271	22,428	0.9	-	3.3	-	-	-

Values for aluminium and zink are monthly averages.

Average flow, Production and Conductivity data from Noranda Forest Inc., Recycled Papers, Control point 0100 (17-5-1991).



DOC and BOD5 data from Noranda Forest Inc., Recycled Papers, Control point 0100 (17-5-1991).

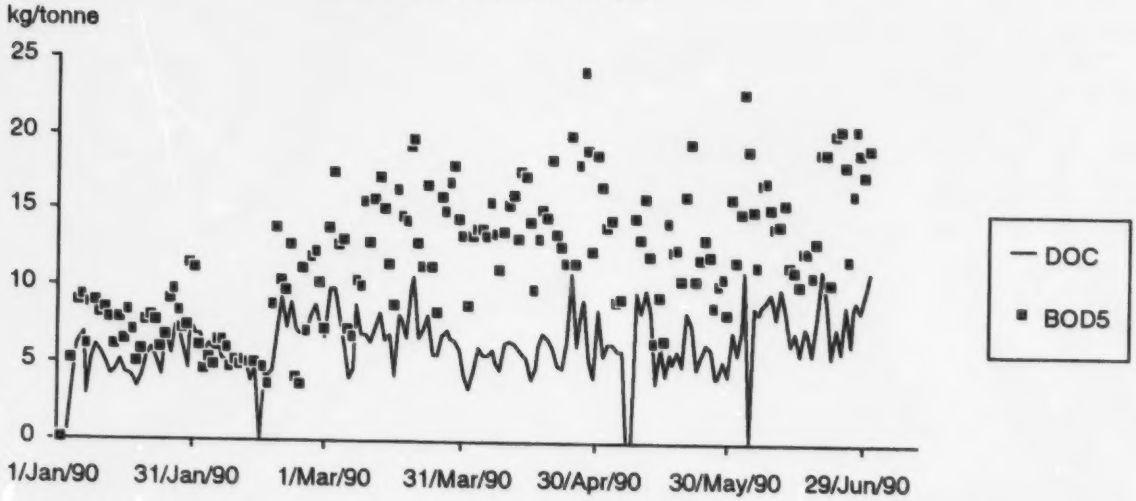


Table 1b. Halogenated volatiles (ATG16). Kimberly-Clark Canada Inc. (St Catherines). (Date: 29-4-1991).

Company: 0000830208 Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	Chloro-methane mg/tonne	Chloro-ethylene mg/tonne	Bromo-methane mg/tonne	Bromodi-chloromethane mg/tonne	Dichloro-methane mg/tonne	1,1-Dichloro-ethane mg/tonne	1,2-Dichloro-ethane mg/tonne	1,1-Dichloro-ethylene mg/tonne
Jan/90	101	9,320	-	-	-	-	0	0	0	-
Feb/90	113	7,200	-	-	-	-	0	0	-	-
Mar/90	107	8,530	-	-	-	-	0	0	-	-
Apr/90	113	7,170	-	-	-	-	0	0	0	-
May/90	102	7,422	-	-	-	-	-	0	-	-
Jun/90	114	7,840	-	-	-	-	0	0	-	-

Company: 0000830208 Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	trans-1,2-Di-chloroethylene mg/tonne	1,2-Dichloro-propane mg/tonne	cis-1,3-Di-chloropropylene mg/tonne	trans-1,3-Di-chloropropylene mg/tonne	Dibromo-ethylene mg/tonne	Trichloro-methane mg/tonne	Dibromo-chloromethane mg/tonne	Tribromo-methane mg/tonne	1,1,2-Tri-chloroethane mg/tonne
Jan/90	101	9,320	-	0	-	-	-	0	-	-	-
Feb/90	113	7,200	-	-	-	-	-	0	-	-	-
Mar/90	107	8,530	-	-	-	-	-	0	-	-	-
Apr/90	113	7,170	-	-	-	-	-	0	-	-	-
May/90	102	7,422	-	-	-	-	-	0	-	-	0
Jun/90	114	7,840	-	-	-	-	-	-	-	-	-

Company: 0000830208 Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	Trichloro-ethylene mg/tonne	Trifluoro-chloromethane mg/tonne	Tetrachloro-methane mg/tonne	1,1,2,2-Tetra-chloroethane mg/tonne	Tetrachloro-ethylene mg/tonne	Chloro-benzene mg/tonne	1,2-Dichloro-benzene mg/tonne	1,3-Dichloro-benzene mg/tonne	1,4-Dichloro-benzene mg/tonne
Jan/90	101	9,320	0	-	-	-	0	-	-	-	-
Feb/90	113	7,200	0	-	-	-	0	-	-	-	-
Mar/90	107	8,530	0	-	-	-	0	-	-	-	-
Apr/90	113	7,170	0	-	-	-	0	-	-	-	-
May/90	102	7,422	0	-	-	-	0	-	-	-	-
Jun/90	114	7,840	0	-	-	-	0	-	-	-	-

Table 2b. Nonhalogenated volatiles (ATG17). Kimberly-Clark Canada Inc. (St Catherines). (Date: 29-4-1991).

Company: 0000830208 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Styrene mg/tonne	Benzene mg/tonne	m,p-Xylene mg/tonne	o-Xylene mg/tonne	Toluene mg/tonne
Jan/90	101	9,320	-	-	0	0	0
Feb/90	113	7,200	-	-	0	-	0
Mar/90	107	8,530	-	-	0	0	0
Apr/90	113	7,170	-	-	0	0	0
May/90	102	7,422	-	-	0	-	0
Jun/90	114	7,840	-	-	0	0	0

Table 9b. Inorganics (ATG 3, 4, 6, 7 & 15). Kimberly-Clark Canada Inc. (St Catherines). (Date: 29-4-1991).

Company: 0000830208 Cntr.pt.: 01 Date	Prod. T/day	Av. flow m3/day	pH	Conductivity µs/cm	NH3 + NH4 g/tonne	NO2+NO3 g/tonne	Total-N g/tonne	Total-P g/tonne	Sulphide g/tonne
Jan/90	101	8,340	6.8	452	8	25	149	10	-
Feb/90	113	8,081	6.6	463	13	11	179	7	-
Mar/90	107	7,745	6.5	398	6	11	290	10	-
Apr/90	113	6,456	6.4	408	7	9	128	5	-
May/90	102	7,422	6.2	396	4	11	73	45	-
Jun/90	114	7,608	6.5	360	7	10	200	13	-

Table 10b. Group and unspecific variables (ATG 1, 5, 8, PP1-3). Kimberly-Clark Canada Inc. (St Catherines). (Date: 29-4-1991).

Company: 0000830208 Cntr.pt.: 01 Date	Prod. T/day	Av. flow m3/tonne	BOD5 Kg/tonne	AOX Kg/tonne	COD Kg/tonne	DOC Kg/tonne	TOC Kg/tonne	TSS Kg/tonne	VSS Kg/tonne	COD/BOD
Jan/90	101	83	1.8	-	4.9	-	-	0.7	-	2.6
Feb/90	113	72	1.9	-	7.5	-	-	0.4	-	3.9
Mar/90	107	72	2.5	-	8.0	-	-	0.7	-	3.2
Apr/90	113	57	2.9	-	9.1	-	-	0.5	-	3.1
May/90	102	73	3.9	-	11.8	-	-	0.5	-	3.0
Jun/90	114	67	3.6	-	10.8	-	-	0.5	-	3.0

Table 3b. Extractable base neutrals (ATG19). Kimberly-Clark Canada Inc. (St Catherines). (Date: 29-4-1991).

Company: 0000830208 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Naphthalene mg/tonne	1-Methyl-naphthalene mg/tonne	2-Methyl-naphthalene mg/tonne	1-Chloro-naphthalene mg/tonne	2-Chloro-naphthalene mg/tonne	Anthracene mg/tonne	Benz[a]-anthracene mg/tonne	Dibenz[a] anthracene mg/tonne
Jan/90	101	9,320	-	-	0	-	-	-	-	-
Feb/90	113	7,200	0	-	0	-	-	-	-	-
Mar/90	107	8,530	0	0	0	-	-	-	-	-
Apr/90	113	7,170	0	0	0	-	-	-	-	-
May/90	102	7,422	0	-	0	-	-	-	-	-
Jun/90	114	7,840	0	0	0	-	-	-	-	-

Company: 0000830208 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Phenanthrene mg/tonne	Acenaphthene mg/tonne	Acenaphthylene mg/tonne	5-Nitro-acenaphthene mg/tonne	Chrysene mg/tonne	Fluoranthene mg/tonne	Benz[b]-fluoranthene mg/tonne	Benz[k] fluoranthene mg/tonne	Fluorene mg/tonne
Jan/90	101	9,320	-	-	-	-	-	-	-	-	-
Feb/90	113	7,200	-	-	-	-	-	-	-	-	-
Mar/90	107	8,530	-	-	-	-	-	-	-	-	-
Apr/90	113	7,170	-	-	-	-	-	-	-	-	-
May/90	102	7,422	-	-	-	-	-	-	-	-	-
Jun/90	114	7,840	-	-	-	-	-	-	-	-	-

Company: 0000830208 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Pyrene mg/tonne	Benz[a]-pyrene mg/tonne	ıdeno[1,2,3-cd pyrene mg/tonne	Perylene mg/tonne	Benz[g,h,i]-perylene mg/tonne	Indole mg/tonne	Camphene mg/tonne
Jan/90	101	9,320	-	-	-	-	-	-	-
Feb/90	113	7,200	-	-	-	-	-	-	-
Mar/90	107	8,530	-	-	-	-	-	0	-
Apr/90	113	7,170	-	-	-	-	-	0	-
May/90	102	7,422	-	-	-	-	-	-	-
Jun/90	114	7,840	-	-	-	-	-	-	-

Table 4b. Acidic extractables (ATG20). Kimberly-Clark Canada Inc. (St Catherines). (Date: 29-4-1991).

Company: 0000830208 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Phenol mg/tonne	m-Cresol mg/tonne	o-Cresol mg/tonne	p-Cresol mg/tonne	2,4-xylenol mg/tonne	4-Chloro-m-cresol mg/tonne	2-Chloro-phenol mg/tonne	2,4-Dichloro-phenol mg/tonne
Jan/90	101	9,320	-	-	-	-	-	-	-	-
Feb/90	113	7,200	0	-	-	-	-	-	-	-
Mar/90	107	8,530	0	-	-	-	-	-	-	-
Apr/90	113	7,170	0	-	-	-	-	-	-	-
May/90	102	7,422	0	-	-	-	-	-	-	-
Jun/90	114	7,840	0	-	-	-	0	-	-	-

Company: 0000830208 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	2,6-Dichloro-phenol mg/tonne	2,3,4-Tri-chlorophenol mg/tonne	2,3,5-Tri-chlorophenol mg/tonne	2,4,5-Tri-chlorophenol mg/tonne	2,4,6-Tri-chlorophenol mg/tonne	2,3,4,5-Tetra-chlorophenol mg/tonne	2,3,4,6-Tetra-chlorophenol mg/tonne	2,3,5,6-Tetra-chlorophenol mg/tonne	Penta-chlorophenol mg/tonne
Jan/90	101	9,320	-	-	-	-	-	-	-	-	-
Feb/90	113	7,200	-	-	-	-	-	-	-	-	-
Mar/90	107	8,530	-	-	-	-	-	-	-	-	-
Apr/90	113	7,170	-	-	-	-	-	-	-	-	-
May/90	102	7,422	-	-	-	-	0	-	-	-	0
Jun/90	114	7,840	-	-	-	-	-	-	-	-	-

Company: 0000830208 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	4-Nitro-phenol mg/tonne	2,4-Dinitro-phenol mg/tonne	4,6-Dinitro-o-cresol mg/tonne
Jan/90	101	9,320	-	-	-
Feb/90	113	7,200	-	-	-
Mar/90	107	8,530	-	-	-
Apr/90	113	7,170	-	-	-
May/90	102	7,422	-	-	-
Jun/90	114	7,840	-	-	-

Table 5b. Chlorinated, neutrals (ATG(23). Kimberly-Clark Canada Inc. (St Catherines). (Date: 29-4-1991).

Company: 0000830208 Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	Hexachloro-ethane mg/tonne	Hexachloro-butadiene mg/tonne	Hexachloro-yclopentadien mg/tonne	1,2,3-Trichloro-benzene mg/tonne	1,2,4-Trichloro-benzene mg/tonne	2,4,5-Trichloro-toluene mg/tonne	1,2,3,4-Tetra-chlorobenzen mg/tonne	1,2,3,5-Tetra-chlorobenzene mg/tonne
Date										
Jan/90	101	9,320	-	-	-	-	-	-	-	-
Feb/90	113	7,200	-	-	-	-	-	-	-	-
Mar/90	107	8,530	-	-	0.0	-	-	-	-	-
Apr/90	113	7,170	-	-	-	-	-	-	-	-
May/90	102	7,422	-	-	-	-	-	-	-	-
Jun/90	114	7,840	-	-	-	-	-	-	-	-

Company: 0000830208 Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	1,2,4,5-Tetra-chlorobenzene mg/tonne	Penta-chlorobenzene mg/tonne	Hexa-chlorobenzene mg/tonne	Octachloro-styrene mg/tonne
Date						
Jan/90	101	9,320	-	-	-	-
Feb/90	113	7,200	-	-	-	-
Mar/90	107	8,530	-	-	-	-
Apr/90	113	7,170	-	-	-	-
May/90	102	7,422	-	-	-	-
Jun/90	114	7,840	-	-	-	-

Table 6b. Chlorinated dioxins, dibenzofuranes and PCB's (ATG(23). Kimberly-Clark Canada Inc. (St Catherines). (Date: 29-4-1991).

Company: 0000830208 Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	2,3,7,8-TCDD µgtonne	Total TCDD µgtonne	Total TCDF µgtonne	Total PCDD µgtonne	Total PCDF µgtonne	Total HxCDD µgtonne	Total HxCDF µgtonne	Total HpCDD µgtonne
Date										
Jan/90	101	9,320	-	-	-	-	-	-	-	-
Mar/90	107	8,530	-	-	0.0	-	-	-	-	-
May/90	102	7,422	-	-	-	-	-	-	-	-

Company: 0000830208 Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	Total HpCDF µg/tonne	OCDD µg/tonne	OCDF µg/tonne	Total PCB's µg/tonne
Date						
Jan/90	101	9,320	-	-	0.0	-
Mar/90	107	8,530	-	-	-	-
May/90	102	7,422	-	-	0.0	-

Table 7b. Fatty and resin acids (ATG 26). Kimberly-Clark Canada Inc. (St Catherines). (Date: 29-4-1991).

Company: 0000830208 Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	Oleic acid g/tonne	Pimaric acid g/tonne	Abietic acid g/tonne	Dehydro-abietic acid g/tonne	Isopimaric acid g/tonne	Levopimaric acid g/tonne	Neoabietic acid g/tonne	Chlorodehydro-abietic acid g/tonne
Date										
Jan/90	101	9,320	-	-	-	6.3	-	-	-	-
Feb/90	113	7,200	-	-	-	0.3	-	-	-	-
Mar/90	107	8,530	-	-	-	0.3	-	-	-	-
Apr/90	113	7,170	-	-	0.0	7.6	-	-	-	-
May/90	102	7,422	0.0	0.0	0.0	25.6	0.0	0.0	-	-
Jun/90	114	7,840	-	0.0	0.0	0.7	-	-	-	-

Company: 0000830208 Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	Dichlorodehydr abietic acid g/tonne	Total resin acids g/tonne	Total resin acids Kg/day	Total resin acids <mg/l>
Date						
Jan/90	101	9,320	-	6.3	1	0.07
Feb/90	113	7,200	-	0.3	0	0.00
Mar/90	107	8,530	-	0.3	0	0.00
Apr/90	113	7,170	-	7.6	1	0.12
May/90	102	7,422	-	25.6	3	0.35
Jun/90	114	7,840	-	0.7	0	0.01

Values for dehydroabietic acid and dichlorodehydroabietic acid are monthly averages

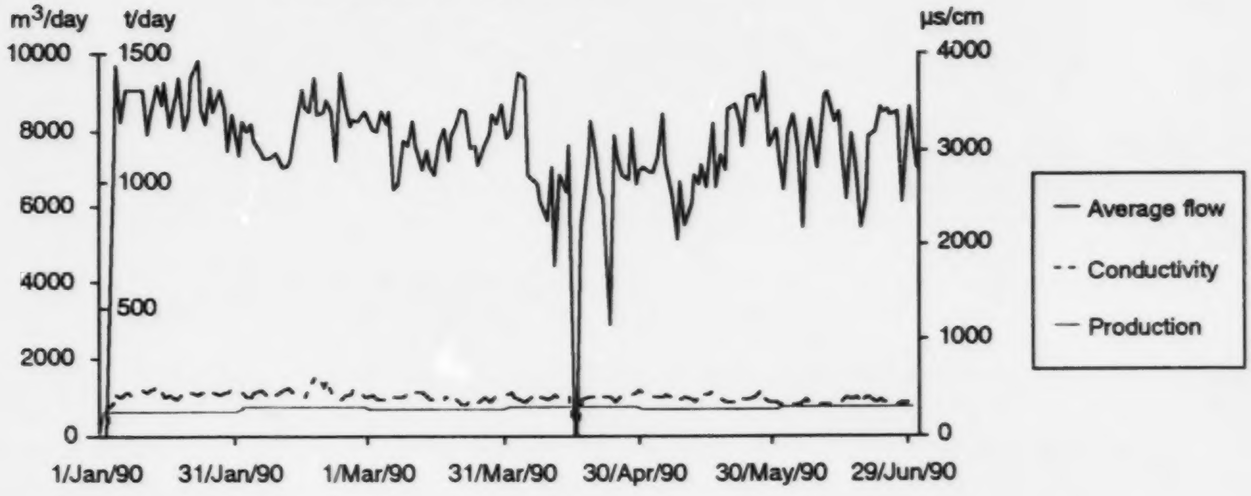
Table 8b. Metals (ATG 9 &12). Kimberly-Clark Canada Inc. (St Catherines). (Date: 29-4-1991).

Company 00008302C Date	Prod. T/day	Daily flow m3/day	Berylium g/tonne	Aluminium g/tonne	Copper g/tonne	Zinc g/tonne	Chromium g/tonne	Nickel g/tonne	Molybdenum g/tonne	Cobalt g/tonne
Jan/90	101	9,320	-	8	-	6.4	-	0.0	0.0	-
Feb/90	113	7,200	-	9	0.0	357.7	-	-	0.0	-
Mar/90	107	8,530	-	10	0.0	14.6	-	0.0	-	-
Apr/90	113	7,170	-	6	0.0	225.5	0.0	-	-	-
May/90	102	7,422	-	10	0.0	40.3	0.0	0.0	-	-
Jun/90	114	7,840	-	7	0.0	6.8	-	0.0	-	-

Company 00008302C Date	Prod. T/day	Daily flow m3/day	Vanadium g/tonne	Silver g/tonne	Lead g/tonne	Cadmium g/tonne	Thallium g/tonne	Mercury g/tonne
Jan/90	101	9,320	-	0.0	-	-	-	-
Feb/90	113	7,200	-	-	0.0	0.00	-	0.00
Mar/90	107	8,530	0.0	-	-	0.00	-	-
Apr/90	113	7,170	-	-	-	-	-	-
May/90	102	7,422	0.0	-	0.0	0.00	-	-
Jun/90	114	7,840	-	-	-	-	-	-

Values for aluminium and zink are monthly averages.

Average flow, Production and Conductivity data from Kimberly-Clark Canada Inc. (St Catherines),
Control point 0100 (14-5-1991).



TSS, COD and BOD5 data from Kimberly-Clark Canada Inc. (St Catherines),
Control point 0100 (14-5-1991).

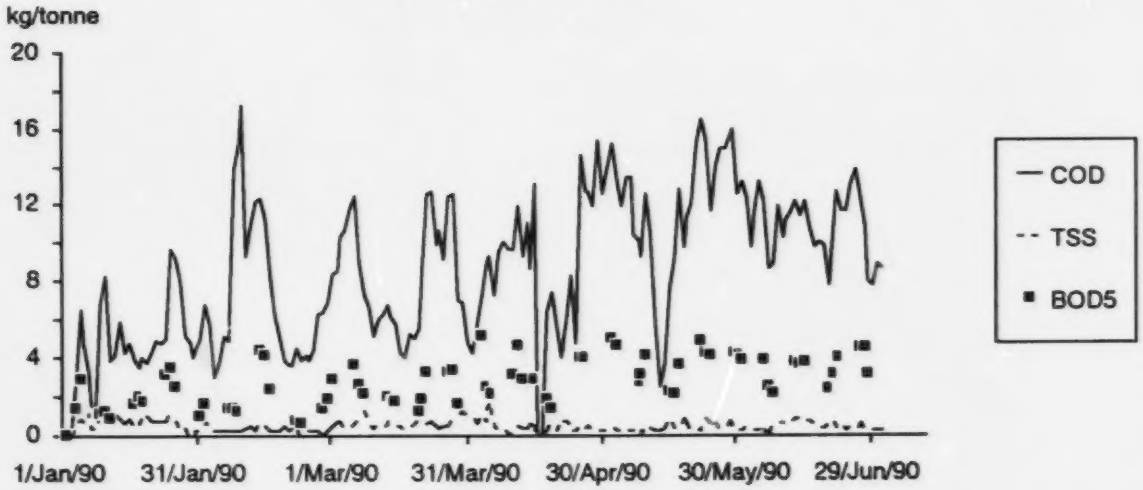


Table 1b. Halogenated volatiles (ATG16). Kimberly-Clark Canada Ltd. (Huntsville). (Date: 29-4-1991).

Company: 0000830109

Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	Chloro-methane mg/tonne	Chloro-ethylene mg/tonne	Bromo-methane mg/tonne	Bromodi-chloromethane mg/tonne	Dichloro-methane mg/tonne	1,1-Dichloro-ethane mg/tonne	1,2-Dichloro-ethane mg/tonne	1,1-Dichloro-ethylene mg/tonne
Jan/90	101	457	-	-	-	-	58	-	-	-
Feb/90	99	1,405	-	-	-	-	-	-	-	-
Mar/90	96	573	-	-	-	-	-	-	-	-
Apr/90	106	1,039	-	-	-	-	-	-	-	-

Company: 0000830109

Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	trans-1,2-Di-chloroethylene mg/tonne	1,2-Dichloro-propane mg/tonne	cis-1,3-Di-chloropropylen mg/tonne	trans-1,3-Di-chloropropylen mg/tonne	Dibromo-ethylene mg/tonne	Trichloro-methane mg/tonne	Dibromo-chloromethane mg/tonne	Tribromo-methane mg/tonne	1,1,2-Tri-chloroethane mg/tonne
Jan/90	101	457	-	-	-	-	-	43	-	-	-
Feb/90	99	1,405	-	-	-	-	-	0	-	-	-
Mar/90	96	573	-	-	-	-	-	0	-	-	-
Apr/90	106	1,039	-	-	-	-	-	0	-	-	-

Company: 0000830109

Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	Trichloro-ethylene mg/tonne	Trifluoro-chloromethane mg/tonne	Tetrachloro-methane mg/tonne	1,1,2,2-Tetra-chloroethane mg/tonne	Tetrachloro-ethylene mg/tonne	Chloro-benzene mg/tonne	1,2-Dichloro-benzene mg/tonne	1,3-Dichloro-benzene mg/tonne	1,4-Dichloro-benzene mg/tonne
Jan/90	101	457	-	12	-	-	-	-	-	-	-
Feb/90	99	1,405	-	-	-	-	-	-	-	-	-
Mar/90	96	573	-	-	-	-	-	-	-	-	-
Apr/90	106	1,039	-	-	-	-	-	-	-	-	-

Table 2b. Nonhalogenated volatiles (ATG17). Kimberly-Clark Canada Ltd. (Huntsville). (Date: 29-4-1991).

Company: 0000830109

Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Styrene mg/tonne	Benzene mg/tonne	m,p-Xylene mg/tonne	o-Xylene mg/tonne	Toluene mg/tonne
Jan/90	101	457	-	-	-	-	-
Feb/90	99	1,405	-	-	-	-	-
Mar/90	96	573	-	-	-	-	-
Apr/90	106	1,039	-	-	-	-	-

Table 9b. Inorganics (ATG 3, 4, 6, 7 & 15). Kimberly-Clark Canada Ltd. (Huntsville). (Date: 29-4-1991).

Company: 0000830109

Cntr.pt.: 01 Date	Prod. T/day	Av. flow m3/day	pH	Conductivity µs/cm	NH3 + NH4 g/tonne	NO2+NO3 g/tonne	Total-N g/tonne	Total-P g/tonne	Sulphide g/tonne
Jan/90	100	868	7.4	486	1	1	37	2	-
Feb/90	104	858	7.2	505	1	1	51	2	-
Mar/90	91	805	7.2	487	1	2	55	3	-
Apr/90	105	984	7.2	479	2	1	82	3	-

Table 10b. Group and unspecific variables (ATG 1, 5, 8, PP1-3). Kimberly-Clark Canada Ltd. (Huntsville). (Date: 29-4-1991).

Company: 0000830109

Cntr.pt.: 01 Date	Prod. T/day	Av. flow m3/tonne	BOD5 Kg/tonne	AOX Kg/tonne	COD Kg/tonne	DOC Kg/tonne	TOC Kg/tonne	TSS Kg/tonne	VSS Kg/tonne	COD/BOD
Jan/90	100	9	0.02	-	0.62	0.00	-	0.04	-	38
Feb/90	104	8	0.02	-	0.60	-	-	0.04	-	26
Mar/90	91	9	0.03	-	0.64	-	-	0.05	-	20
Apr/90	105	9	0.03	-	0.74	-	-	0.06	-	26

Table 3b. Extractable base neutrals (ATG19). Kimberly-Clark Canada Ltd. (Huntsville). (Date: 29-4-1991).

Company: 0000830109 Cntr.pt.: 01 Date	Prod T/day	Daily flow m3/day	Naphthalene mg/tonne	1-Methyl-naphthalene mg/tonne	2-Methyl-naphthalene mg/tonne	1-Chloro-naphthalene mg/tonne	2-Chloro-naphthalene mg/tonne	Anthracene mg/tonne	Benz[a]-anthracene mg/tonne	Dibenz[a] anthracene mg/tonne
Jan/90	101	457	-	-	-	-	-	-	-	-
Feb/90	99	1,405	-	-	-	-	-	-	-	-
Mar/90	96	573	-	-	-	-	-	-	-	-
Apr/90	106	1,039	-	-	-	-	-	-	-	-

Company: 0000830109 Cntr.pt.: 01 Date	Prod T/day	Daily flow m3/day	Phenanthrene mg/tonne	Acenaphthene mg/tonne	Acenaphthylene mg/tonne	5-Nitro-acenaphthene mg/tonne	Chrysene mg/tonne	Fluoranthene mg/tonne	Benz[b]-fluoranthene mg/tonne	Benz[k] fluoranthene mg/tonne	Fluorene mg/tonne
Jan/90	101	457	-	-	-	-	-	-	-	-	-
Feb/90	99	1,405	-	-	-	-	-	-	-	-	-
Mar/90	96	573	-	-	-	-	-	-	-	-	-
Apr/90	106	1,039	-	-	-	-	-	-	-	-	-

Company: 0000830109 Cntr.pt.: 01 Date	Prod T/day	Daily flow m3/day	Pyrene mg/tonne	Benz[a]-pyrene mg/tonne	ideno[1,2,3-cd pyrene mg/tonne	Perylene mg/tonne	Benz[g,h,i]-perylene mg/tonne	Indole mg/tonne	Camphene mg/tonne
Jan/90	101	457	-	-	-	-	-	-	-
Feb/90	99	1,405	-	-	-	-	-	-	-
Mar/90	96	573	-	-	-	-	-	-	-
Apr/90	106	1,039	-	-	-	-	-	-	-

Table 4b. Acidic extractables (ATG20). Kimberly-Clark Canada Ltd. (Huntsville). (Date: 29-4-1991).

Company: 0000830109 Cntr.pt.: 01 Date	Prod T/day	Daily flow m3/day	Phenol mg/tonne	m-Cresol mg/tonne	o-Cresol mg/tonne	p-Cresol mg/tonne	2,4-xylenol mg/tonne	4-Chloro-m-cresol mg/tonne	2-Chloro-phenol mg/tonne	2,4-Dichloro-phenol mg/tonne
Jan/90	101	457	-	-	-	-	-	-	-	-
Feb/90	99	1,405	-	-	-	-	-	-	-	-
Mar/90	96	573	-	-	-	-	-	-	-	-
Apr/90	106	1,039	-	-	-	-	-	-	-	-

Company: 0000830109 Cntr.pt.: 01 Date	Prod T/day	Daily flow m3/day	2,6-Dichloro-phenol mg/tonne	2,3,4-Tri-chlorophenol mg/tonne	2,3,5-Tri-chlorophenol mg/tonne	2,4,5-Tri-chlorophenol mg/tonne	2,4,6-Tri-chlorophenol mg/tonne	2,3,4,5-Tetra-chlorophenol mg/tonne	2,3,4,6-Tetra-chlorophenol mg/tonne	2,3,5,6-Tetra-chlorophenol mg/tonne	Penta-chlorophenol mg/tonne
Jan/90	101	457	-	-	-	-	-	-	-	-	-
Feb/90	99	1,405	-	-	-	-	-	-	-	-	-
Mar/90	96	573	-	-	-	-	-	-	-	-	-
Apr/90	106	1,039	-	-	-	-	-	-	-	-	-

Company: 0000830109 Cntr.pt.: 01 Date	Prod T/day	Daily flow m3/day	4-Nitro-phenol mg/tonne	2,4-Dinitro-phenol mg/tonne	4,6-Dinitro-o-cresol mg/tonne
Jan/90	101	457	-	-	-
Feb/90	99	1,405	-	-	-
Mar/90	98	573	-	-	-
Apr/90	106	1,039	-	-	-

Table 5b. Chlorinated, neutrals (ATG(23). Kimberly-Clark Canada Ltd. (Huntsville). (Date: 29-4-1991).

Company: 0000830109 Cntr pt.: 01	Prod T/day	Daily flow m3/day	Hexachloro-ethane mg/tonne	Hexachloro-butadiene mg/tonne	Hexachloro- yclopentadien mg/tonne	1,2,3-Trichloro-benzene mg/tonne	1,2,4-Trichloro-benzene mg/tonne	2,4,5-Trichloro-toluene mg/tonne	1,2,3,4-Tetra-chlorobenzene mg/tonne	1,2,3,5-Tetra-chlorobenzene mg/tonne
Date										
Jan/90	101	457	-	-	-	-	-	-	-	-
Feb/90	99	1,405	0.00	0.00	-	-	-	-	-	-
Mar/90	96	573	-	0.00	-	-	-	-	-	-
Apr/90	106	1,039	-	-	-	-	-	-	-	-

Company: 0000830109 Cntr pt.: 01	Prod T/day	Daily flow m3/day	1,2,4,5-Tetra-chlorobenzene mg/tonne	Penta-chlorobenzene mg/tonne	Hexa-chlorobenzene mg/tonne	Octachloro-styrene mg/tonne
Date						
Jan/90	101	457	-	-	-	-
Feb/90	99	1,405	-	-	-	-
Mar/90	96	573	-	-	-	-
Apr/90	106	1,039	-	-	-	-

Table 6b. Chlorinated dioxine, dibenzofuranes and PCB's (ATG(23). Kimberly-Clark Canada Ltd. (Huntsville). (Date: 29-4-1991).

Company: 0000830109 Cntr pt.: 01	Prod T/day	Daily flow m3/day	2,3,7,8-TCDD µgtonne	Total TCDD µgtonne	Total TCDF µgtonne	Total PCDD µgtonne	Total PCDF µgtonne	Total HxCDD µgtonne	Total HxCDF µgtonne	Total HpCDD µgtonne
Date										
Jan/90	101	457	-	-	-	-	-	-	-	-
Mar/90	56	573	-	0.00	-	0.00	-	0.00	-	-

Company: 0000830109 Cntr pt.: 01	Prod T/day	Daily flow m3/day	Total HpCDF µg/tonne	OCDD µg/tonne	OCDF µg/tonne	Total PCB's µg/tonne
Date						
Jan/90	101	457	-	0.48	-	-
Mar/90	56	573	-	0.00	-	-

Table 7b. Fatty and resin acids (ATG 26). Kimberly-Clark Canada Ltd. (Huntsville). (Date: 29-4-1991).

Company: 0000830109 Cntr pt.: 01	Prod T/day	Daily flow m3/day	Oleic acid g/tonne	Pimaric acid g/tonne	Abietic acid g/tonne	Dehydro-abietic acid g/tonne	Isopimaric acid g/tonne	Levopimaric acid g/tonne	Neoabietic acid g/tonne	Chlorodehydro-abietic acid g/tonne
Date										
Jan/90	101	457	-	-	-	0.043	-	-	-	-
Feb/90	99	1,405	-	-	-	0.043	-	-	-	-
Mar/90	96	573	-	-	-	0.101	-	-	-	-
Apr/90	106	1,039	0.000	-	-	0.046	-	-	-	-

Company: 0000830109 Cntr pt.: 01	Prod. T/day	Daily flow m3/day	Dichlorodehydr abietic acid g/tonne	Total resin acids g/tonne	Total resin acids Kg/day	Total resin acids <mg/l>
Date						
Jan/90	101	457	-	0.043	0.004	0.010
Feb/90	99	1,405	-	0.043	0.004	0.003
Mar/90	96	573	-	0.101	0.010	0.017
Apr/90	106	1,039	-	0.046	0.005	0.005

Values for dehydroabietic acid and dichlorodehydroabietic acid are monthly averages

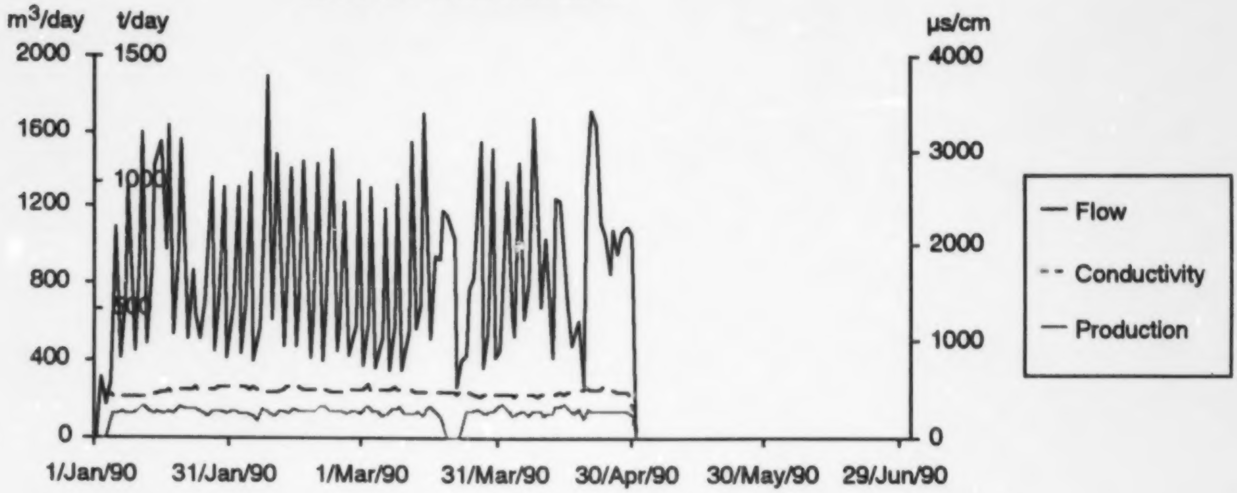
Table 9b. Metals (ATG 9 &12). Kimberly-Clark Canada Ltd. (Huntsville). (Date: 29-4-1991).

Company 00008301C Date	Prod. T/day	Daily flow m3/day	Berylium g/tonne	Aluminium g/tonne	Copper g/tonne	Zinc g/tonne	Chromium g/tonne	Nickel g/tonne	Molybdenum g/tonne	Cobalt g/tonne
Jan/90	101	457	-	0	-	0.1	-	-	-	-
Feb/90	99	1,405	-	0	-	0.2	-	-	-	-
Mar/90	96	573	-	0	0.0	0.1	-	-	-	-
Apr/90	106	1,039	-	1	0.0	0.1	0.0	-	-	-

Company 00008301C Date	Prod. T/day	Daily flow m3/day	Vanadium g/tonne	Silver g/tonne	Lead g/tonne	Cadmium g/tonne	Thallium g/tonne	Mercury g/tonne
Jan/90	101	457	-	-	0.2	-	-	-
Feb/90	99	1,405	-	-	-	0.00	-	-
Mar/90	96	573	-	-	-	-	-	-
Apr/90	106	1,039	-	-	-	-	-	-

Values for aluminium and zink are monthly averages.

Flow, Production and Conductivity data from Kimberly-Clark Canada Ltd. (Huntsville), Control point 0100 (14-5-1991).



TSS, COD and BOD5 data from Kimberly-Clark Canada Ltd. (Huntsville), Control point 0100 (14-5-1991).

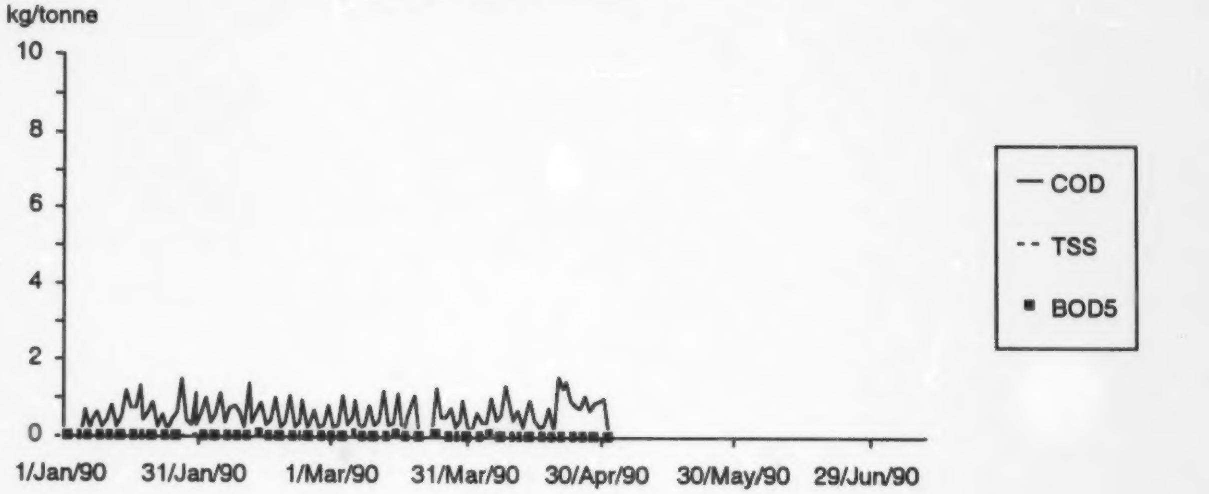


Table 1b. Halogenated volatiles (ATG16). Trent Valley, Paperboard Industries Corporation. (Date: 15-5-1991).

Company: 0001750009

Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	Chloro-methane mg/tonne	Chloro-ethylene mg/tonne	Bromo-methane mg/tonne	Bromodi-chloromethane mg/tonne	Dichloro-methane mg/tonne	1,1-Dichloro-ethane mg/tonne	1,2-Dichloro-ethane mg/tonne	1,1-Dichloro-ethylene mg/tonne
Jan/90	314	2,936	-	-	-	-	-	0	-	0
Feb/90	333	3,765	0	-	-	-	0	0	-	0
Mar/90	310	4,303	0	-	0	-	0	0	-	0
Apr/90	260	2,919	-	-	0	-	-	0	-	0
May/90	273	3,160	0	-	0	-	-	0	-	0
Jun/90	300	4,450	-	-	-	-	-	-	-	0

Company: 0001750009

Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	trans-1,2-Di-chloroethylene mg/tonne	1,2-Dichloro-propane mg/tonne	cis-1,3-Di-chloropropylene mg/tonne	trans-1,3-Di-chloropropylene mg/tonne	Dibromo-ethylene mg/tonne	Trichloro-methane mg/tonne	Dibromo-chloromethane mg/tonne	Tribromo-methane mg/tonne	1,1,2-Tri-chloroethane mg/tonne
Jan/90	314	2,936	-	-	-	-	-	0	-	-	-
Feb/90	333	3,765	-	-	-	-	-	0	-	-	-
Mar/90	310	4,303	-	0	-	-	-	0	-	-	-
Apr/90	260	2,919	-	-	-	-	-	0	-	-	-
May/90	273	3,160	-	-	-	-	-	-	-	-	-
Jun/90	300	4,450	-	-	-	-	-	-	-	-	-

Company: 0001750009

Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	Trichloro-ethylene mg/tonne	Trifluoro-chloromethane mg/tonne	Tetrachloro-methane mg/tonne	1,1,2,2-Tetra-chloroethane mg/tonne	Tetrachloro-ethylene mg/tonne	Chloro-benzene mg/tonne	1,2-Dichloro-benzene mg/tonne	1,3-Dichloro-benzene mg/tonne	1,4-Dichloro-benzene mg/tonne
Jan/90	314	2,936	-	-	-	-	-	-	-	-	-
Feb/90	333	3,765	-	-	-	-	0	-	-	0	0
Mar/90	310	4,303	-	-	-	-	0	-	-	-	0
Apr/90	260	2,919	-	-	-	-	-	-	-	-	0
May/90	273	3,160	-	-	-	-	0	-	-	-	-
Jun/90	300	4,450	-	-	-	-	-	-	-	-	-

Table 2b. Nonhalogenated volatiles (ATG17). Trent Valley, Paperboard Industries Corporation. (Date: 15-5-1991).

Company: 0001750009

Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	Styrene mg/tonne	Benzene mg/tonne	m,p-Xylene mg/tonne	o-Xylene mg/tonne	Toluene mg/tonne
Date							
Jan/90	314	2,936	0	0	-	0	0
Feb/90	333	3,765	-	0	0	0	0
Feb/90	310	4,303	-	-	0	-	0
Mar/90	260	2,919	0	-	0	0	0
Apr/90	273	3,160	0	-	0	0	0
May/90	300	4,450	-	0	-	-	0

Table 9b. Inorganics (ATG 3, 4, 6, 7 & 15). Trent Valley, Paperboard Industries Corporation. (Date: 15-5-1991).

Company: 0001750009

Cntr.pt.: 01	Prod. T/day	Av. flow m3/day	pH	Conductivity µs/cm	NH3 + NH4 g/tonne	NO2+NO3 g/tonne	Total-N g/tonne	Total-P g/tonne	Sulphide g/tonne
Date									
Jan/90	312	3,274	6.4	929	0	0	40	4	-
Feb/90	297	4,035	6.6	812	3	4	80	5	-
Mar/90	306	3,349	6.8	971	5	2	49	7	-
Apr/90	295	3,684	6.9	930	2	4	49	2	-
May/90	299	3,801	6.7	737	1	0	26	2	-
Jun/90	320	3,731	6.3	787	0	0	43	3	-

Table 10b. Group and unspecific variables (ATG 1, 5, 8, PP1-3). Trent Valley, Paperboard Industries Corporation. (Date: 15-5-1991)

Company: 0001750009

Cntr.pt.: 01	Prod. T/day	Av. flow m3/tonne	BOD5 Kg/tonne	AOX Kg/tonne	COD Kg/tonne	DOC Kg/tonne	TOC Kg/tonne	TSS Kg/tonne	VSS Kg/tonne	COD/BOD
Date										
Jan/90	312	10	5.1	-	12.1	0.0	-	1.9	-	2.4
Feb/90	297	14	5.1	-	11.5	0.0	-	2.4	-	2.2
Mar/90	306	11	4.9	-	9.6	0.0	-	1.1	-	2.0
Apr/90	295	12	4.9	-	10.6	-	-	1.5	-	2.2
May/90	299	13	5.1	-	11.2	-	-	1.5	-	2.2
Jun/90	320	12	5.1	-	11.9	-	-	1.8	-	2.3

Table 3b. Extractable base neutrals (ATG19). Trent Valley, Paperboard Industries Corporation. (Date: 15-5-1991).

Company: 0001750009 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Naphthalene mg/tonne	1-Methyl-naphthalene mg/tonne	2-Methyl-naphthalene mg/tonne	1-Chloro-naphthalene mg/tonne	2-Chloro-naphthalene mg/tonne	Anthracene mg/tonne	Benz[a]-anthracene mg/tonne	Dibenz[a] anthracene mg/tonne
Jan/90	314	2,936	-	-	-	-	-	-	-	-
Feb/90	333	3,765	0	-	-	-	-	-	-	-
Mar/90	260	2,919	0	-	-	-	-	-	-	-
Apr/90	273	3,160	-	-	-	-	-	-	-	-
May/90	300	4,450	-	-	-	-	-	-	-	-
Jun/90	338	3,675	0	-	-	-	-	-	-	-

Company: 0001750009 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Phenanthrene mg/tonne	Acenaphthene mg/tonne	Acenaphthylene mg/tonne	5-Nitro-acenaphthene mg/tonne	Chrysene mg/tonne	Fluoranthene mg/tonne	Benz[b]-fluoranthene mg/tonne	Benz[k] fluoranthene mg/tonne	Fluorene mg/tonne
Jan/90	314	2,936	-	-	-	-	-	-	-	-	-
Feb/90	333	3,765	-	-	-	-	-	-	-	-	-
Mar/90	260	2,919	-	-	-	-	-	-	-	-	-
Apr/90	273	3,160	-	-	-	-	-	-	-	-	-
May/90	300	4,450	-	-	-	-	-	-	-	-	-
Jun/90	338	3,675	-	-	-	0	-	-	-	-	-

Company: 0001750009 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Pyrene mg/tonne	Benz[a]-pyrene mg/tonne	ideno[1,2,3-cd pyrene mg/tonne	Perylene mg/tonne	Benz[g,h,i]-perylene mg/tonne	Indole mg/tonne	Camphene mg/tonne
Jan/90	314	2,936	-	-	-	-	-	-	-
Feb/90	333	3,765	-	-	-	-	-	-	-
Mar/90	260	2,919	-	-	-	-	-	-	-
Apr/90	273	3,160	-	-	-	-	-	-	-
May/90	300	4,450	-	-	-	-	-	-	-
Jun/90	338	3,675	-	-	-	-	-	-	-

Table 4b. Acidic extractables (ATG20). Trent Valley, Paperboard Industries Corporation. (Date: 15-5-1991).

Company: 0001750009 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	Phenol mg/tonne	m-Cresol mg/tonne	o-Cresol mg/tonne	p-Cresol mg/tonne	2,4-xylenol mg/tonne	4-Chloro-m-cresol mg/tonne	2-Chloro-phenol mg/tonne	2,4-Dichloro-phenol mg/tonne
Jan/90	314	2,936	0	-	-	-	-	-	-	-
Feb/90	333	3,765	0	0	-	0	-	-	-	-
Mar/90	260	2,919	0	0	-	0	-	-	-	-
Apr/90	273	3,160	-	0	0	0	-	0	-	-
May/90	300	4,450	0	0	0	0	-	-	-	-
Jun/90	338	3,675	-	-	-	-	-	-	-	-

Company: 0001750009 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	2,6-Dichloro-phenol mg/tonne	2,3,4-Tri-chlorophenol mg/tonne	2,3,5-Tri-chlorophenol mg/tonne	2,4,5-Tri-chlorophenol mg/tonne	2,4,6-Tri-chlorophenol mg/tonne	2,3,4,5-Tetra-chlorophenol mg/tonne	2,3,4,6-Tetra-chlorophenol mg/tonne	2,3,5,6-Tetra-chlorophenol mg/tonne	Penta-chlorophenol mg/tonne
Jan/90	314	2,936	-	-	-	-	-	-	-	-	-
Feb/90	333	3,765	-	-	-	-	-	-	-	-	-
Mar/90	260	2,919	-	-	-	-	-	-	-	-	-
Apr/90	273	3,160	-	-	-	-	-	-	-	-	0
May/90	300	4,450	-	-	-	-	-	-	-	-	0
Jun/90	338	3,675	-	-	-	-	-	-	-	-	-

Company: 0001750009 Cntr.pt.: 01 Date	Prod. T/day	Daily flow m3/day	4-Nitro-phenol mg/tonne	2,4-Dinitro-phenol mg/tonne	4,6-Dinitro-o-cresol mg/tonne
Jan/90	314	2,936	-	-	-
Feb/90	333	3,765	-	-	-
Mar/90	260	2,919	-	-	-
Apr/90	273	3,160	-	-	-
May/90	300	4,450	-	-	-
Jun/90	338	3,675	-	-	-

Table 5b. Chlorinated, neutrals (ATG(23). Trent Valley, Paperboard Industries Corporation. (Date: 15-5-1991)

Company: 0001750009 Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	Hexachloro-ethane mg/tonne	Hexachloro-butadiene mg/tonne	Hexachloro- yclopentadien mg/tonne	1,2,3-Trichloro-benzene mg/tonne	1,2,4-Trichloro-benzene mg/tonne	2,4,5-Trichloro-toluene mg/tonne	1,2,3,4-Tetra-chlorobenzene mg/tonne	1,2,3,5-Tetra-chlorobenzene mg/tonne
Date										
Jan/90	314	2,936	-	-	-	-	-	-	-	-
Feb/90	333	3,765	-	-	-	-	0.0	-	-	-
Mar/90	260	2,919	-	-	-	-	-	-	-	-
Apr/90	273	3,160	-	-	-	-	0.0	-	-	-
May/90	300	4,450	-	-	-	-	0.0	-	-	-
Jun/90	338	3,675	-	-	-	-	0.0	-	-	-

Company: 0001750009 Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	1,2,4,5-Tetra-chlorobenzene mg/tonne	Penta-chlorobenzene mg/tonne	Hexa-chlorobenzene mg/tonne	Octachloro-styrene mg/tonne
Date						
Jan/90	314	2,936	-	-	-	-
Feb/90	333	3,765	-	-	-	-
Mar/90	260	2,919	-	-	-	-
Apr/90	273	3,160	-	-	-	-
May/90	300	4,450	-	-	-	-
Jun/90	338	3,675	-	-	-	-

Table 6b. Chlorinated dioxins, dibenzofuranes and PCB's (ATG(23). Trent Valley, Paperboard Industries Corporation. (Date: 15-5-1991).

Company: 0001750009 Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	2,3,7,8-TCDD µgtonne	Total TCDD µgtonne	Total TCDF µgtonne	Total PCDD µgtonne	Total PCDF µgtonne	Total HxCDD µgtonne	Total HxCDF µgtonne	Total HpCDD µgtonne
Date										
Apr/90	273	3,160	-	-	-	-	-	-	-	-

Company: 0001750009 Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	Total HpCDF µg/tonne	OCDD µg/tonne	OCDF µg/tonne	Total PCB's µg/tonne
Date						
Apr/90	273	3,160	-	-	-	-

Table 7b. Fatty and resin acids (ATG 26). Trent Valley, Paperboard Industries Corporation. (Date: 15-5-1991)

Company: 0001750009 Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	Oleic acid g/tonne	Pimaric acid g/tonne	Abietic acid g/tonne	Dehydro-abietic acid g/tonne	Isopimaric acid g/tonne	Levopimaric acid g/tonne	Neoabietic acid g/tonne	Chlorodehydro-abietic acid g/tonne
Date										
Jan/90	314	2,936	-	0.0	0.0	13.1	0.0	-	-	-
Feb/90	333	3,765	-	-	0.0	8.0	0.0	-	-	-
Mar/90	260	2,919	-	-	-	1.0	0.0	-	-	-
Apr/90	273	3,160	-	-	0.0	1.4	0.0	-	-	-
May/90	300	4,450	0.0	0.0	0.0	2.4	0.0	-	-	-
Jun/90	338	3,675	-	-	0.0	39.7	0.0	0.0	0.0	-

Company: 0001750009 Cntr.pt.: 01	Prod. T/day	Daily flow m3/day	Dichlorodehydr abietic acid g/tonne	Total resin acids g/tonne	Total resin acids Kg/day	Total resin acids <mg/l>
Date						
Jan/90	314	2,936	-	13.1	4	1.40
Feb/90	333	3,765	-	8.0	3	0.71
Mar/90	260	2,919	-	1.0	0	0.09
Apr/90	273	3,160	-	1.4	0	0.12
May/90	300	4,450	-	2.4	1	0.16
Jun/90	338	3,675	-	39.7	13	3.66

Values for dehydroabietic acid and dichlorodehydroabietic acid are monthly averages

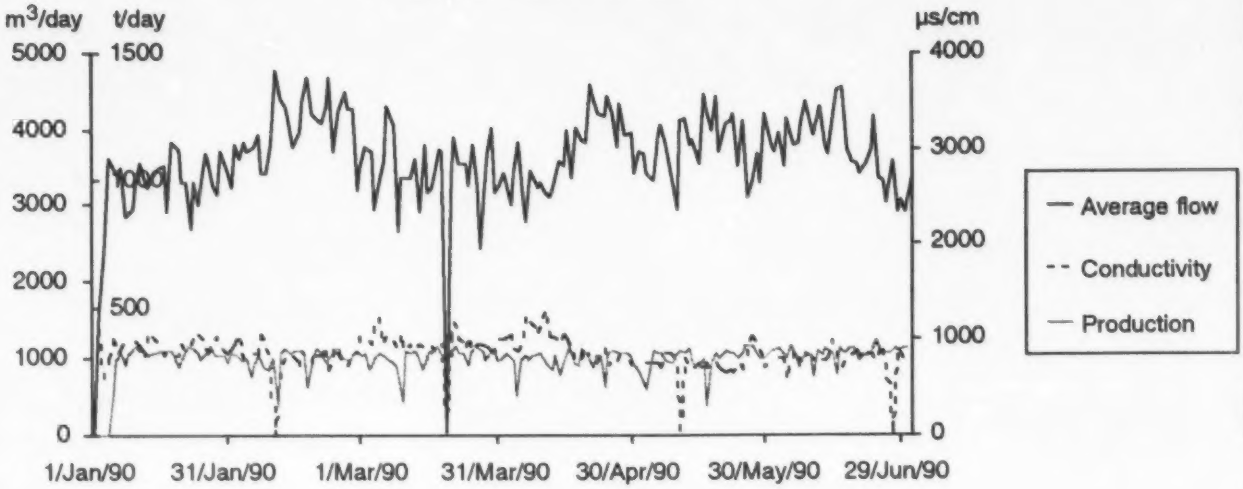
Table 8b. Metals (ATG 9 &12). Trent Valley, Paperboard Industries Corporation. (Date: 15-5-1991).

Company 00017500C Date	Prod. T/day	Daily flow m3/day	Jan/90 Jan/90 g/tonne	Aluminium g/tonne	Copper g/tonne	Zinc g/tonne	Chromium g/tonne	Nickel g/tonne	Molybdenum g/tonne	Cobalt g/tonne
Jan/90	314	2,936	-	59	0.0	1.4	0.0	0.0	-	-
Feb/90	333	3,765	-	52	0.0	1.6	0.0	0.0	-	-
Mar/90	260	2,919	-	49	0.0	4.4	0.0	0.0	-	-
Apr/90	273	3,160	-	71	0.0	1.7	0.0	0.0	-	-
May/90	300	4,450	-	31	-	1.3	0.0	0.0	-	0.0
Jun/90	338	3,675	-	32	0.0	1.3	-	-	-	-

Company 00017500C Date	Prod. T/day	Daily flow m3/day	Vanadium g/tonne	Silver g/tonne	Lead g/tonne	Cadmium g/tonne	Thallium g/tonne	Mercury g/tonne
Jan/90	314	2,936	0.0	-	0.0	0.00	-	-
Feb/90	333	3,765	0.0	-	0.0	0.00	-	-
Mar/90	260	2,919	0.0	-	0.0	0.00	-	-
Apr/90	273	3,160	0.0	-	-	-	-	-
May/90	300	4,450	0.0	-	0.0	0.00	0.00	-
Jun/90	338	3,675	-	-	-	-	-	-

Values for aluminium and zink are monthly averages.

Average flow, Production and Conductivity data from Trent Valley, Paperboard Industries Corporation, Control point 0100 (17-5-1991).



TSS, COD and BOD data from Trent Valley, Paperboard Industries Corporation, Control point 0100 (17-5-1991).

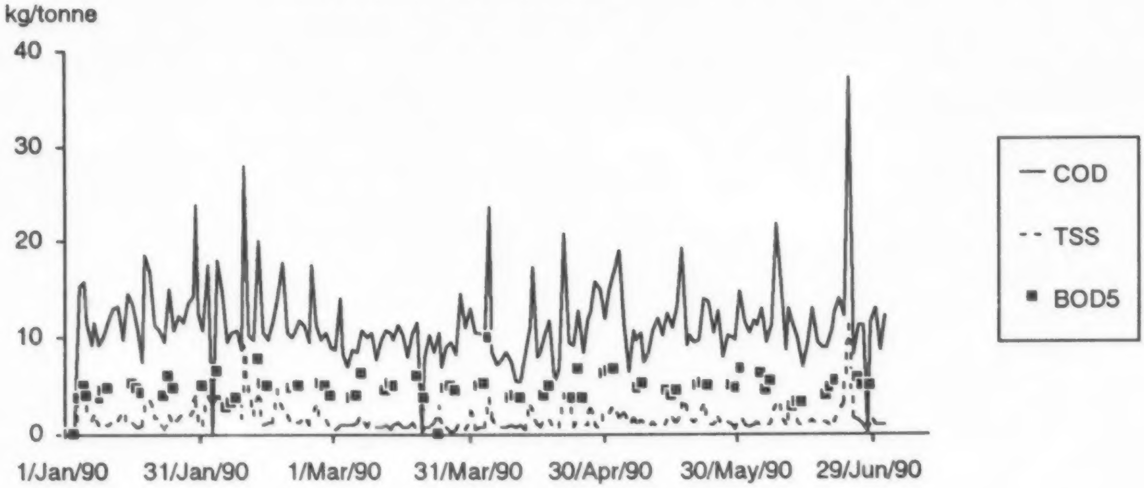


Table 1b. Halogenated volatiles (ATG16). Strathcona Paper Company (Napanee). (Date: 2-5-1991).

Company: 0001740000

Cntr.pt.: 2C	Prod. T/day	Daily flow m3/day	Chloro-methane mg/tonne	Chloro-ethylene mg/tonne	Bromo-methane mg/tonne	Bromodi-chloromethane mg/tonne	Dichloro-methane mg/tonne	1,1-Dichloro-ethane mg/tonne	1,2-Dichloro-ethane mg/tonne	1,1-Dichloro-ethylene mg/tonne
Jan/90	180	3,154	-	-	-	-	37	-	-	-
Feb/90	161	3,965	813	-	39	-	-	-	-	-
Mar/90	205	4,568	-	-	-	-	105	-	-	-
Apr/90	181	4,628	59	-	284	-	-	-	-	-
May/90	182	4,541	473	-	647	-	75	-	-	-
Jun/90	156	3,530	-	-	-	-	-	-	-	-

Company: 0001740000

Cntr.pt.: 2C	Prod. T/day	Daily flow m3/day	trans-1,2-Di-chloroethylene mg/tonne	1,2-Dichloro-propane mg/tonne	cis-1,3-Di-chloropropylen mg/tonne	trans-1,3-Di-chloropropylen mg/tonne	Dibromo-ethylene mg/tonne	Trichloro-methane mg/tonne	Dibromo-chloromethane mg/tonne	Tribromo-methane mg/tonne	1,1,2-Tri-chloroethane mg/tonne
Jan/90	180	3,154	-	-	-	-	-	67	-	-	-
Feb/90	161	3,965	-	-	-	-	-	39	-	-	-
Mar/90	205	4,568	-	-	-	-	-	53	-	-	-
Apr/90	181	4,628	-	-	-	-	-	151	-	-	-
May/90	182	4,541	-	-	-	-	-	249	-	-	-
Jun/90	156	3,530	-	-	-	-	-	-	-	-	-

Company: 0001740000

Cntr.pt.: 2C	Prod. T/day	Daily flow m3/day	Trichloro-ethylene mg/tonne	Trifluoro-chloromethane mg/tonne	Tetrachloro-methane mg/tonne	1,1,2,2-Tetra-chloroethane mg/tonne	Tetrachloro-ethylene mg/tonne	Chloro-benzene mg/tonne	1,2-Dichloro-benzene mg/tonne	1,3-Dichloro-benzene mg/tonne	1,4-Dichloro-benzene mg/tonne
Jan/90	180	3,154	-	-	-	-	-	-	-	-	-
Feb/90	161	3,965	-	-	-	-	-	-	-	-	-
Mar/90	205	4,568	-	-	-	-	-	-	-	-	-
Apr/90	181	4,628	-	-	-	-	-	-	-	-	-
May/90	182	4,541	-	-	-	-	-	-	-	-	-
Jun/90	156	3,530	-	-	-	-	-	-	-	-	-

Table 2b. Nonhalogenated volatiles (ATG17). Strathcona Paper Company (Napanee). (Date: 2-5-1991).

Company: 0001740000

Cntr.pt.: 2C Date	Prod. T/day	Daily flow m3/day	Styrene mg/tonne	Benzene mg/tonne	m,p-Xylene mg/tonne	o-Xylene mg/tonne	Toluene mg/tonne
Jan/90	180	3,154	-	-	-	-	105
Feb/90	161	3,965	-	-	-	-	69
Mar/90	205	4,568	-	-	11	-	10
Apr/90	181	4,628	-	10	9	-	56
May/90	182	4,541	-	-	-	-	12
Jun/90	156	3,530	-	-	-	-	10

Table 9b. Inorganics (ATG 3, 4, 6, 7 & 15). Strathcona Paper Company (Napanee). (Date: 2-5-1991).

Company: 0001740000

Cntr.pt.: 2C Date	Prod. T/day	Av. flow m3/day	pH	Conductivity µs/cm	NH3 + NH4 g/tonne	NO2+NO3 g/tonne	Total-N g/tonne	Total-P g/tonne	Sulphide g/tonne
Jan/90	164	3,392	7.2	700	23	0	177	6	-
Feb/90	171	3,655	6.8	681	15	0	235	9	-
Mar/90	188	3,884	6.6	659	3	0	248	12	-
Apr/90	182	4,488	6.7	638	4	0	179	10	-
May/90	182	3,928	7.4	697	28	0	247	11	-
Jun/90	174	3,609	7.3	727	29	1	245	11	-

Table 10b. Group and unspecific variables (ATG 1, 5, 8, PP1-3). Strathcona Paper Company (Napanee). (Date: 2-5-1991).

Company: 0001740000

Cntr.pt.: 2C Date	Prod. T/day	Av. flow m3/tonne	BOD5 Kg/tonne	AOX Kg/tonne	COD Kg/tonne	DOC Kg/tonne	TOC Kg/tonne	TSS Kg/tonne	VSS Kg/tonne	COD/BOD
Jan/90	164	21	3.1	-	8.2	-	-	0.8	0.7	2.7
Feb/90	171	21	4.9	-	13.8	-	-	1.0	1.2	2.8
Mar/90	188	21	5.8	-	15.2	-	-	1.2	1.5	2.6
Apr/90	182	25	4.5	-	15.8	-	-	1.6	1.7	3.5
May/90	182	22	1.7	-	8.2	-	-	1.5	1.2	4.9
Jun/90	174	21	0.9	-	6.5	-	-	1.6	1.0	6.9

Table 3b. Extractable base neutrals (ATG19). Strathcona Paper Company (Napanee). (Date: 2-5-1991).

Company: 0001740000 Cntr.pt.: 2(	Prod. T/day	Daily flow m3/day	Naphthalene mg/tonne	1-Methyl-naphthalene mg/tonne	2-Methyl-naphthalene mg/tonne	1-Chloro-naphthalene mg/tonne	2-Chloro-naphthalene mg/tonne	Anthracene mg/tonne	Benz[a]-anthracene mg/tonne	Dibenz[a] anthracene mg/tonne
Date										
Jan/90	180	3,154	-	-	-	-	-	-	-	-
Feb/90	161	3,965	-	-	-	-	-	-	-	-
Mar/90	205	4,568	-	-	-	-	-	-	-	-
Apr/90	181	4,628	-	-	-	-	-	-	-	-
May/90	182	4,541	-	-	-	-	-	-	-	-
Jun/90	156	3,530	-	-	-	-	-	-	-	-

Company: 0001740000 Cntr.pt.: 2(	Prod. T/day	Daily flow m3/day	Phenanthrene mg/tonne	Acenaphthene mg/tonne	Acenaphthylene mg/tonne	5-Nitro-acenaphthene mg/tonne	Chrysene mg/tonne	Fluoranthene mg/tonne	Benz[b]-fluoranthene mg/tonne	Benz[k] fluoranthene mg/tonne	Fluorene mg/tonne
Date											
Jan/90	180	3,154	-	-	-	-	-	-	-	-	-
Feb/90	161	3,965	-	-	-	-	-	-	-	-	-
Mar/90	205	4,568	-	-	-	-	-	-	-	-	-
Apr/90	181	4,628	-	-	-	-	-	-	-	-	-
May/90	182	4,541	-	-	-	-	-	-	-	-	-
Jun/90	156	3,530	-	-	-	-	-	-	-	-	-

Company: 0001740000 Cntr.pt.: 2(	Prod. T/day	Daily flow m3/day	Pyrene mg/tonne	Benz[a]-pyrene mg/tonne	ıdeno[1,2,3-cd pyrene mg/tonne	Perylene mg/tonne	Benz[g,h,i]-perylene mg/tonne	Indole mg/tonne	Camphene mg/tonne
Date									
Jan/90	180	3,154	-	-	-	-	-	-	-
Feb/90	161	3,965	-	43	-	-	-	-	-
Mar/90	205	4,568	-	-	-	-	-	-	-
Apr/90	181	4,628	-	-	-	-	-	-	-
May/90	182	4,541	-	-	-	-	-	-	-
Jun/90	156	3,530	-	-	-	-	-	91	-

Table 4b. Acidic extractables (ATG20). Strathcona Paper Company (Napanee). (Date: 2-5-1991).

Company: 0001740000 Cntr.pt.: 2(	Prod. T/day	Daily flow m3/day	Phenol mg/tonne	m-Cresol mg/tonne	o-Cresol mg/tonne	p-Cresol mg/tonne	2,4-xylenol mg/tonne	4-Chloro-m-cresol mg/tonne	2-Chloro-phenol mg/tonne	2,4-Dichloro-phenol mg/tonne
Date										
Jan/90	180	3,154	152	137	-	456	-	-	-	-
Feb/90	161	3,965	640	197	-	1,601	-	-	-	-
Mar/90	205	4,568	490	203	-	824	-	-	-	-
Apr/90	181	4,628	588	95	16	435	-	8	-	-
May/90	182	4,541	167	-	-	946	-	-	-	-
Jun/90	156	3,530	63	-	-	235	-	-	-	-

Company: 0001740000 Cntr.pt.: 2(	Prod. T/day	Daily flow m3/day	2,6-Dichloro-phenol mg/tonne	2,3,4-Tri-chlorophenol mg/tonne	2,3,5-Tri-chlorophenol mg/tonne	2,4,5-Tri-chlorophenol mg/tonne	2,4,6-Tri-chlorophenol mg/tonne	2,3,4,5-Tetra-chlorophenol mg/tonne	2,3,4,6-Tetra-chlorophenol mg/tonne	2,3,5,6-Tetra-chlorophenol mg/tonne	Penta-chlorophenol mg/tonne
Date											
Jan/90	180	3,154	-	-	-	-	-	-	-	-	-
Feb/90	161	3,965	-	-	-	-	-	-	-	-	-
Mar/90	205	4,568	-	-	-	-	-	-	-	-	-
Apr/90	181	4,628	-	-	-	-	-	-	-	-	89
May/90	182	4,541	-	-	-	-	-	-	-	-	-
Jun/90	156	3,530	-	-	-	-	-	-	-	-	-

Company: 0001740000 Cntr.pt.: 2(	Prod. T/day	Daily flow m3/day	4-Nitro-phenol mg/tonne	2,4-Dinitro-phenol mg/tonne	4,6-Dinitro-o-cresol mg/tonne
Date					
Jan/90	180	3,154	-	-	-
Feb/90	161	3,965	-	-	-
Mar/90	205	4,568	-	-	-
Apr/90	181	4,628	-	-	-
May/90	182	4,541	-	-	-
Jun/90	156	3,530	-	-	-

Table 5b. Chlorinated, neutrals (ATG(23). Strathcona Paper Company (Napanee). (Date: 2-5-1991).

Company: 0001740000 Cntr.pt.: 2(Date	Prod. T/day	Daily flow m3/day	Hexachloro-ethane mg/tonne	Hexachloro-butadiene mg/tonne	Hexachloro-yclopentadien mg/tonne	1,2,3-Trichloro-benzene mg/tonne	1,2,4-Trichloro-benzene mg/tonne	2,4,5-Trichloro-toluene mg/tonne	1,2,3,4-Tetra-chlorobenzene mg/tonne	1,2,3,5-Tetra-chlorobenzene mg/tonne
Jan/90	180	3,154	-	-	-	-	-	-	0.1	-
Feb/90	161	3,965	-	-	-	-	-	-	-	-
Mar/90	205	4,568	-	-	-	-	0.0	0.0	-	-
Apr/90	181	4,628	-	-	-	-	-	-	-	-
May/90	182	4,541	-	-	-	-	-	-	-	-
Jun/90	156	3,530	-	-	-	-	0.1	-	-	-

Company: 0001740000 Cntr.pt.: 2(Date	Prod. T/day	Daily flow m3/day	1,2,4,5-Tetra-chlorobenzene mg/tonne	Penta-chlorobenzene mg/tonne	Hexa-chlorobenzene mg/tonne	Octachloro-styrene mg/tonne
Jan/90	180	3,154	-	0.2	-	-
Feb/90	161	3,965	-	-	-	-
Mar/90	205	4,568	-	-	-	-
Apr/90	181	4,628	-	-	-	-
May/90	182	4,541	-	-	-	-
Jun/90	156	3,530	-	-	-	-

Table 6b. Chlorinated dioxins, dibenzofuranes and PCB's (ATG(23). Strathcona Paper Company (Napanee). (Date: 2-5-1991).

Company: 0001740000 Cntr.pt.: 2(Date	Prod. T/day	Daily flow m3/day	2,3,7,8-TCDD µg/tonne	Total TCDD µg/tonne	Total TCDF µg/tonne	Total PCDD µg/tonne	Total PCDF µg/tonne	Total HxCDD µg/tonne	Total HxCDF µg/tonne	Total HpCDD µg/tonne
May/90	182	4,541	-	-	-	-	-	-	-	-

Company: 0001740000 Cntr.pt.: 2(Date	Prod. T/day	Daily flow m3/day	Total HpCDF µg/tonne	OCDD µg/tonne	OCDF µg/tonne	Total PCB's µg/tonne
May/90	182	4,541	-	-	-	-

Table 7b. Fatty and resin acids (ATG 26). Strathcona Paper Company (Napanee). (Date: 2-5-1991).

Company: 0001740000 Cntr.pt.: 2(Date	Prod. T/day	Daily flow m3/day	Oleic acid g/tonne	Pimaric acid g/tonne	Abietic acid g/tonne	Dehydro-abietic acid g/tonne	Isopimaric acid g/tonne	Levopimaric acid g/tonne	Neoabietic acid g/tonne	Chlorodehydro-abietic acid g/tonne
Jan/90	180	3,154	-	-	-	4.7	-	-	-	-
Feb/90	161	3,965	4.9	1.2	0.6	9.1	1.5	-	-	-
Mar/90	205	4,568	-	1.5	-	1.4	-	-	0.8	0.6
Apr/90	181	4,628	-	0.4	0.2	4.1	-	-	0.3	-
May/90	182	4,541	0.4	-	-	0.8	-	-	-	-
Jun/90	156	3,530	-	-	-	0.6	-	-	-	-

Company: 0001740000 Cntr.pt.: 2(Date	Prod. T/day	Daily flow m3/day	Dichlorodehydr abietic acid g/tonne	Total resin acids g/tonne	Total resin acids Kg/day	Total resin acids <mg/l>
Jan/90	180	3,154	-	4.7	1	0.27
Feb/90	161	3,965	-	12.4	2	0.50
Mar/90	205	4,568	-	4.2	1	0.19
Apr/90	181	4,628	-	5.0	1	0.20
May/90	182	4,541	-	0.8	0	0.03
Jun/90	156	3,530	-	0.6	0	0.03

Values for dehydroabietic acid and dichlorodehydroabietic acid are monthly averages

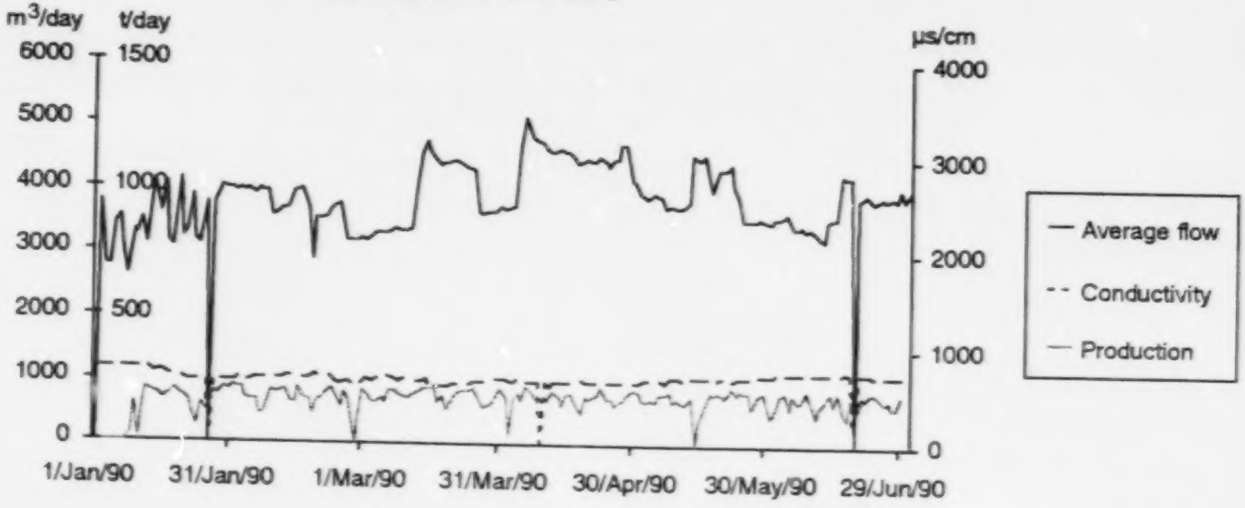
Table 8b. Metals (ATG 9 &12). Strathcona Paper Company (Napanee). (Date: 2-5-1991).

Company 00017400C	Prod. T/day	Daily flow m3/day	Berylium g/tonne	Aluminium g/tonne	Copper g/tonne	Zinc g/tonne	Chromium g/tonne	Nickel g/tonne	Molybdenum g/tonne	Cobalt g/tonne
Date										
Jan/90	180	3,154	-	9	0.3	1.1	0.3	0.1	-	-
Feb/90	161	3,965	-	15	-	0.4	-	-	0.2	-
Mar/90	205	4,568	-	14	0.2	0.3	0.3	0.2	0.6	-
Apr/90	181	4,628	-	100	0.7	0.3	-	-	-	-
May/90	182	4,541	-	10	0.1	0.2	0.1	-	-	-
Jun/90	156	3,530	-	8	-	0.3	-	-	-	-

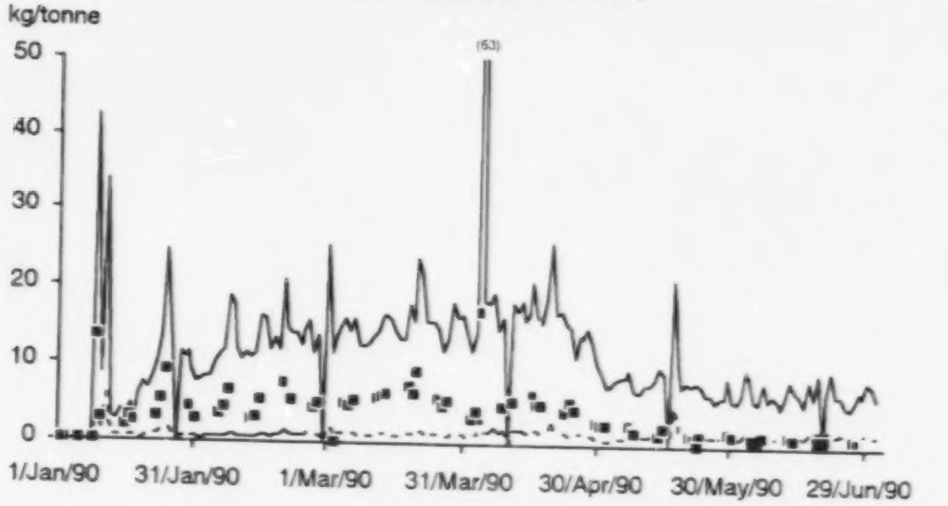
Company 00017400C	Prod. T/day	Daily flow m3/day	Vanadium g/tonne	Silver g/tonne	Lead g/tonne	Cadmium g/tonne	Thallium g/tonne	Mercury g/tonne
Date								
Jan/90	180	3,154	0.3	-	0.1	0.01	-	-
Feb/90	161	3,965	0.2	-	-	0.01	-	-
Mar/90	205	4,568	0.4	-	0.1	0.01	-	-
Apr/90	181	4,628	0.6	-	-	-	-	-
May/90	182	4,541	-	-	-	-	-	-
Jun/90	156	3,530	-	-	-	-	-	-

Values for aluminium and zink are monthly averages.

Average flow, Production and Conductivity data from Strathcona Paper Company (Napanee), Control point 200 (17-5-1991).



TSS, COD and BOD5 data from Strathcona Paper Company (Napanee), Control point 200 (17-5-1991).



Appendix C

Mill Contact Reports

Reports with varying degrees of detail were prepared by team members on visits to mills and other establishments, and on contacts with various organizations in addition to Ontario mills and the Ministry. The most useful of these reports are collected in this appendix.

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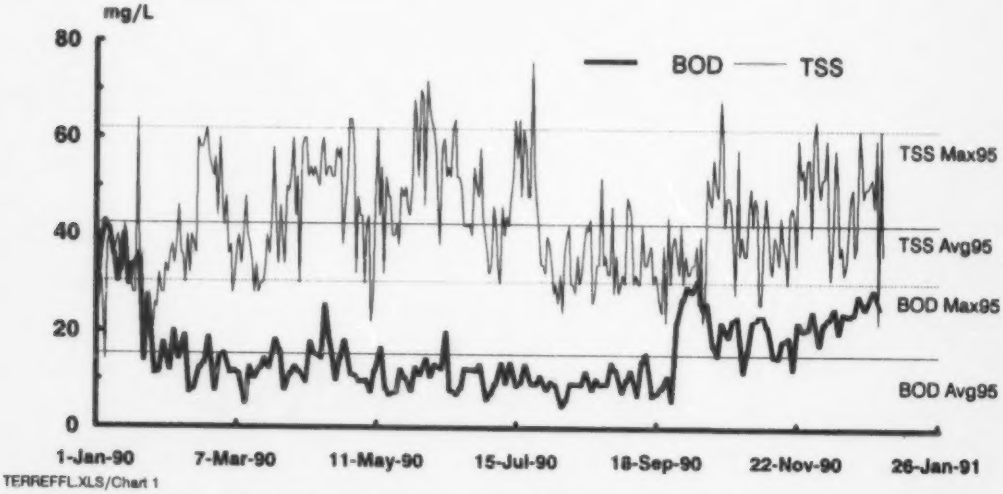
Kimberly-Clark, Terrace Bay, Ontario

This Ontario mill produces 1,150 tonnes per day of hardwood and softwood bleached kraft market pulp. External treatment consists of mechanical, primary clarification followed by an aerated stabilization basin. Refer also to Appendix A for further details on this mill.

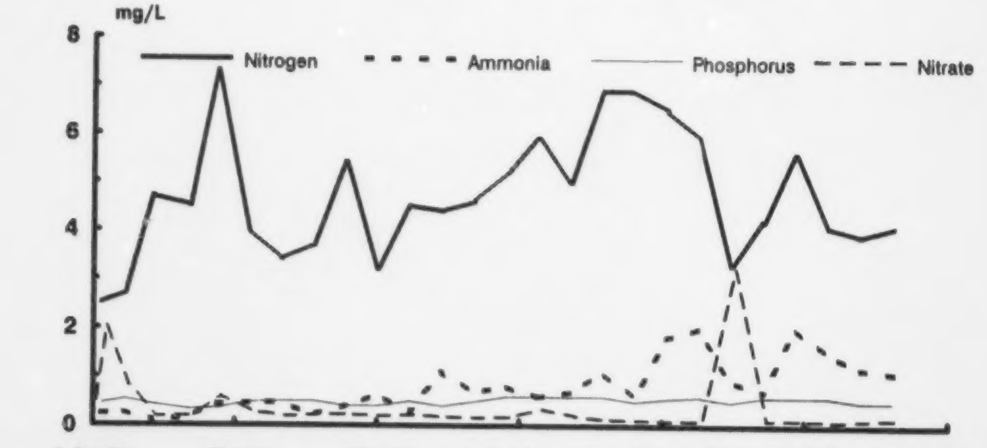
Final effluent wastewater discharges average 89 m³/tonne. The daily effluent discharge concentrations are summarized in Figure C.1.



TERREFFL.XLS/Chart 1

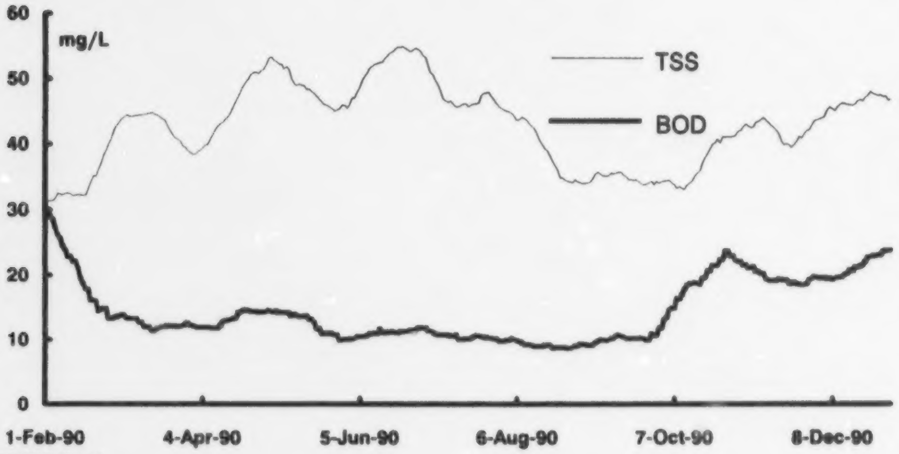
Figure C.1 Kimberly-Clark, Terrace Bay, BOD and TSS discharges

The nutrient discharges for the first six months of 1990 are summarized in Figure C.2. These do not display any seasonal bias, and the phosphorus discharge is noticeably low.



MILL19.XLS Chart 1

Figure C.2 Kimberly-Clark, Terrace Bay, daily nutrient discharges

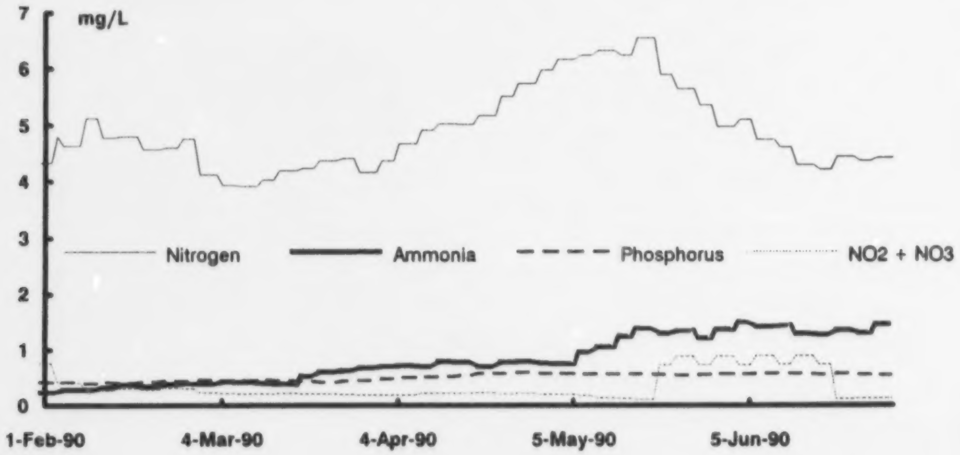


TERREFFL.XLS Chart 3

Figure C.3 Kimberly-Clark, Terrace Bay, BOD and TSS discharges, 30-day rolling averages

The 30-day moving averages for BOD and TSS discharges from the mill provide an indication of the maximum monthly average discharges.

It is noticeable that there is no visible seasonal variation in TSS discharges, and it is debatable whether BOD discharges vary seasonally. This mill reported minimum effluent discharge temperature of 12 deg C, so it is somewhat surprising to that effluent quality does not show an obvious drop in winter. However, daily effluent temperature data were not available.



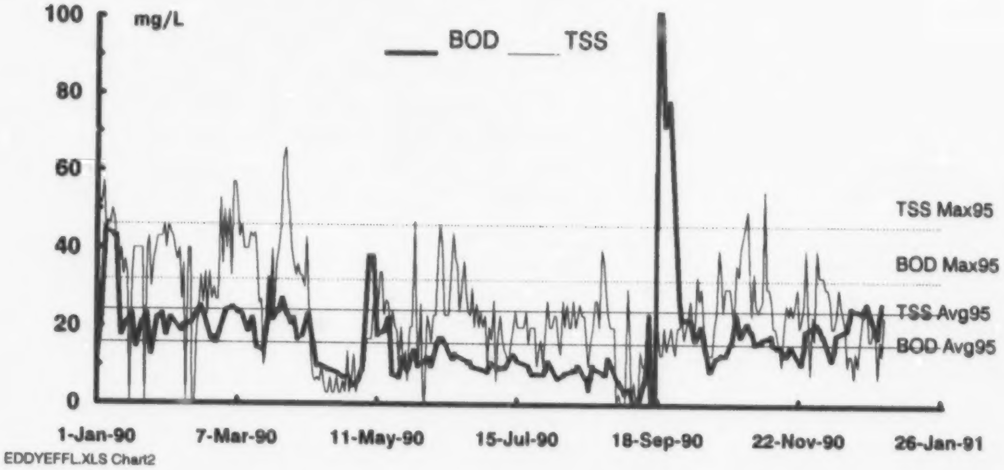
MILL19.XLS Chart 2

Figure C.4 Kimberly-Clark ,Terrace Bay, Nutrient discharges, 30-day rolling average

E. B. Eddy, Espanola, Ontario

The E. B. Eddy mill at Espanola manufactures fully bleached hardwood and softwood market pulps and also has a small paper mill on-site. Refer to the mill data sheet in Appendix A for further information.

The mill was built in the late nineteenth century, and has been modernized several times since. Two oxygen delignification lines have been operating for a number of years, and an ASB was installed to treat all effluents in the mid 1980s. The effluent is consistently non-toxic to trout and *Daphnia magna*. BOD, and TSS discharges are summarized in Figures C.5.

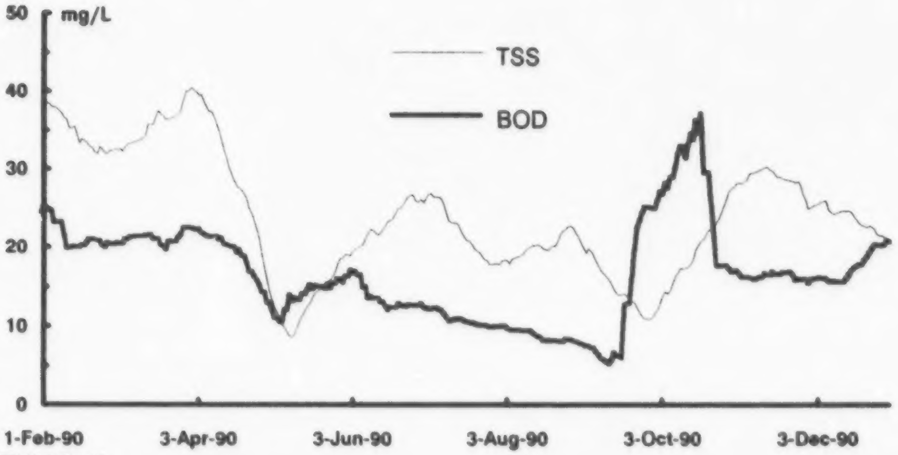


Source: MISA 1990

Figure C.5 E.B. Eddy, Espanola, Effluent BOD and TSS discharges

The BOD and TSS discharge concentrations during 1990 were lower than those considered as BAT in this report, and discussed in Chapter 5. The effluent flow is quite high, about 105 m³/tonne product, so the overall performance can be expected to improve if in-plant measures are implemented to reduce flows.

The 30 day rolling averages for BOD and TSS discharges shown in Figure C.6 suggest somewhat better performance in summer than in winter, although the average BOD discharge for the three coldest months (January, February and March) is essentially identical to the annual average.



EDDYEFFL.XLS Chart 3

Figure C.6 E.B. Eddy, Espanola, BOD and TSS discharges, 30-day rolling averages

Nutrient discharges

Nutrient discharges were measured as follows during the 1990 MISA sampling program:

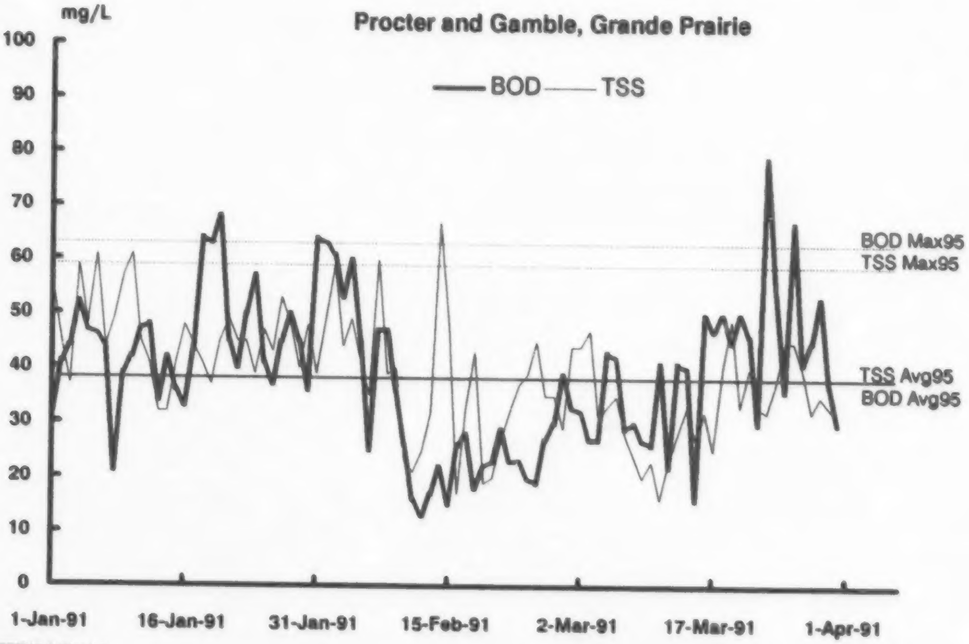
	Average discharge	99th percentile
Total phosphorus	0.51 mg/L	0.97 mg/L
Ammonia nitrogen	1.0 mg/L	2.6 mg/L

Procter and Gamble, Grande Prairie Alberta

Procter and Gamble have operated a bleached kraft mill near Grande Prairie, Alberta since the early 1970s. It was originally designed to produce 675 tonne/day fully bleached market kraft, but various minor upgrades have raised production to approximately 850 tonne/day. The mill design included an extensive spill control system, a primary clarifier and a two-stage aerated stabilization basin with 12 days nominal hydraulic retention time.

A Kamyr continuous digester produces softwood pulp for the bleaching operation which uses 70% chlorine dioxide substitution in the chlorination stage (personal communication, I. McKenzie Alberta Environment, 1991).

The BOD and TSS discharges for the 1991 winter season are summarized in Figure C.7.



PROCTER.XLS Chart 2

Figure C.7 Procter and Gamble, Grande Prairie, Effluent BOD and TSS discharges

Weldwood, Hinton, Alberta

The Weldwood Canada mill at Hinton, Alberta was commissioned in the mid 1950's, and has had various owners. It was originally designed to produce 450 tonnes/day fully bleached market kraft, but various minor upgrades and a major rebuild have raised production to approximately 1100 tonnes/day. The mill originally had only a simple settling basin for some of the effluent, and no spill protection facilities. A primary clarifier and aerated stabilization basin were installed in the late 1960s. Presently it has an extensive spill control system, a primary clarifier and a two-stage aerated stabilization basin with a 6 day nominal hydraulic retention time, and 3000 HP installed aeration equipment.

The following description of this mill is extracted from a paper by Andrews (1991).

> In 1990 a $385 million expansion project was completed, at the mill. An integral part of this project was the inclusion of the best available technology for environmental control. The project included a MCC Kamyr digester, 0_2 delignification, a R-8 ClO_2 plant, in-house spill recovery and an upgraded waste water treatment system.
>
> The level of chlorine dioxide substitution was been increased from the pre-expansion level of 5% to the current normal operating rate of 45%. On a regular monthly basis, dictated by market demand, 100% substitution runs are also produced.
>
> Treated effluent AOX discharge has been very stable between 1.0 to 1.1 kg/ADt[1] with the mill operating at an average 18 Kappa to the bleach plant and a monthly average 50% ClO_2 substitution level (includes some 100% ClO_2 production runs). All 1990 and 1991 year to date acute toxicity tests have shown the treated effluent to be non-toxic. Both rainbow trout and *Daphnia magna* test specimens have shown 100% survival in 100% treated effluent concentrations during these bioassays.
>
> Liquor spill recovery systems, a closed brown stock system, a new high rate steam stripper, a green liquor dregs solid handling and disposal system and increased ASB aeration are components of the project which are believed to have been beneficial in meeting the licence toxicity requirements. The resin acid content in the final treated effluent is measured on a monthly grab sample of the ASB discharge prior to mixing with the clear water bypass. These results are typically below the detection limit of 0.01 ppm.
>
> Analyses for 2,3,7,8 TCDD are in the range of non-detect to 5 ppq, while 2,3,7,8 TCDF furan has been between 10 to 25 ppq.

The average effluent flow for the period November 1990 to June 1991 was 103,000 m^3/day, which was equivalent to 102 m^3/tonne product.

---

[1] *Alberta Environment reports show an average of 0.96 kg/tonne.*

Effluent BOD and TSS extracted from Alberta Environment files are summarized in Figures C.8 and C.9.

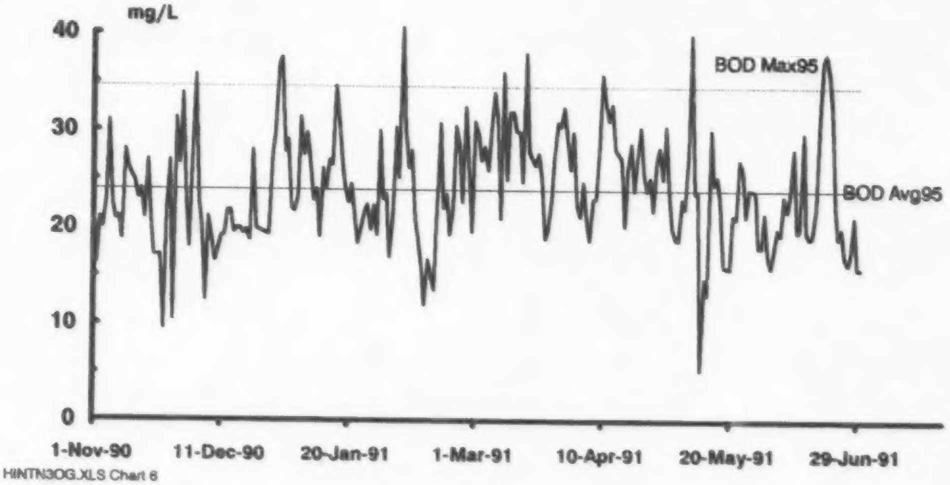


Figure C.8 Weldwood, Hinton, Effluent BOD discharges

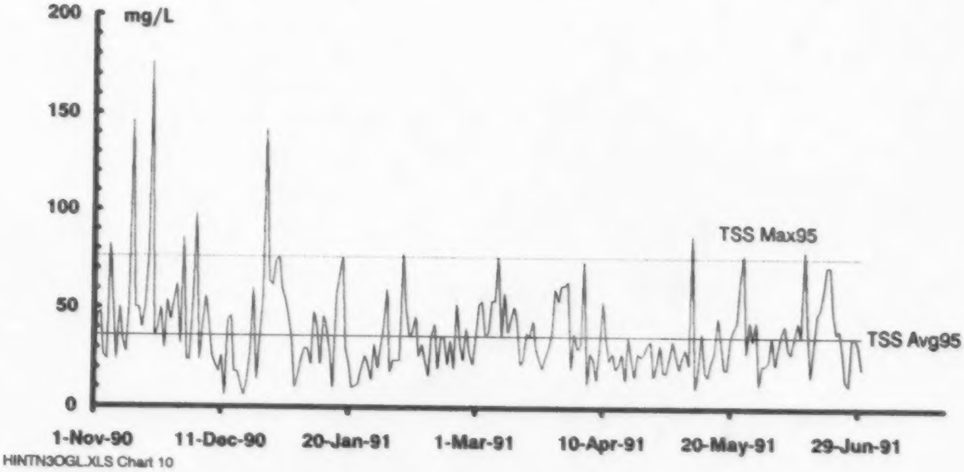


Figure C.9 Weldwood, Hinton, Effluent TSS discharges

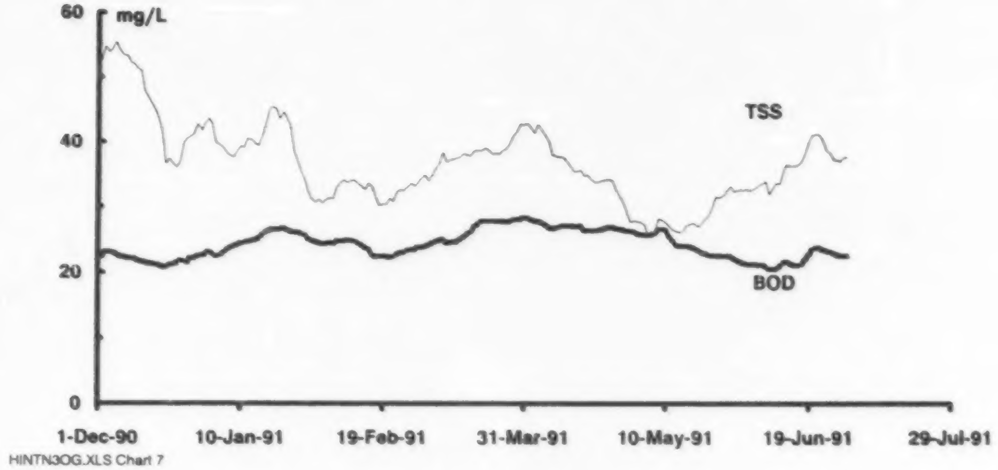


Figure C.10 Weldwood, Hinton, BOD and TSS discharges, 30-day rolling averages

Nutrients

Personal contact with the mill indicated that nitrogen was the only nutrient added during the period for which the effluent data is shown here. The phosphorus discharges shown in Figure C.11 are therefore surprisingly high. The municipal sewage from the town of Hinton is treated along with the mill effluent. Calculation by the authors based on the available data indicate that the town sewage may be a significant contributor to the high phosphorus discharge, but there were not sufficient data available to resolve the question.

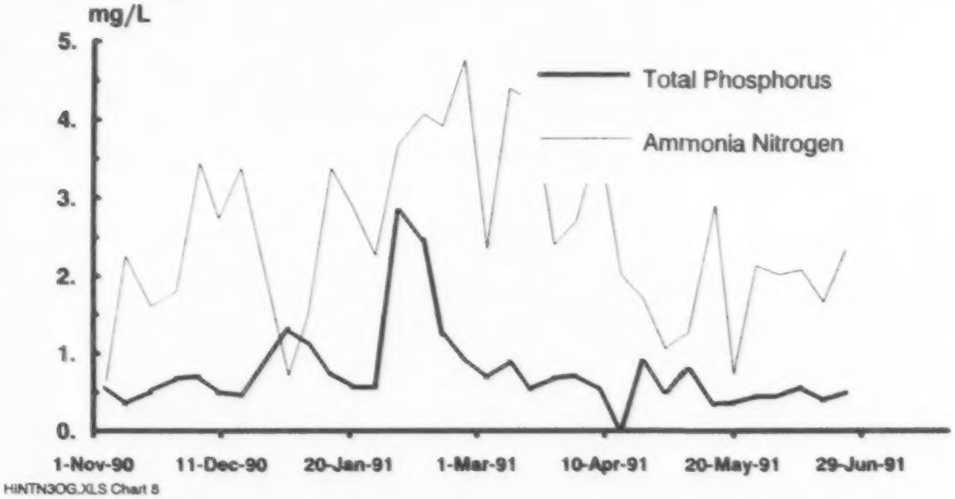


Figure C.11 Weldwood, Hinton, Phosphorus, and ammonia nitrogen discharges in effluent

Alberta Newsprint, Whitecourt, Alberta

The 700 tonnes per day Alberta Newsprint Co. mill at Whitecourt was commissioned in 1990. It manufactures newsprint from thermomechanical pulp, and was designed to operate without any addition of chemical pulp. Equipment is installed for operation as a CTMP mill, but chemicals had not been used at the time of writing.

The effluent treatment system is based on the activated sludge process, and includes a spill basin, influent equalization basin and a post treatment aerated polishing basin. The Activated Sludge Treatment system incorporates an anoxic selector, and is believed to be the first application of this technology in the Canadian pulp and paper industry. The flowsheet is shown in Figure C.12 and the design criteria and performance data for the system are presented in Table C.0. Provision is included in the design for control of the activated sludge basin temperature by alternative routing of cooling water and, as a last resort, steam heating of the effluent. This has been required only during mill shutdown in extremely cold weather.

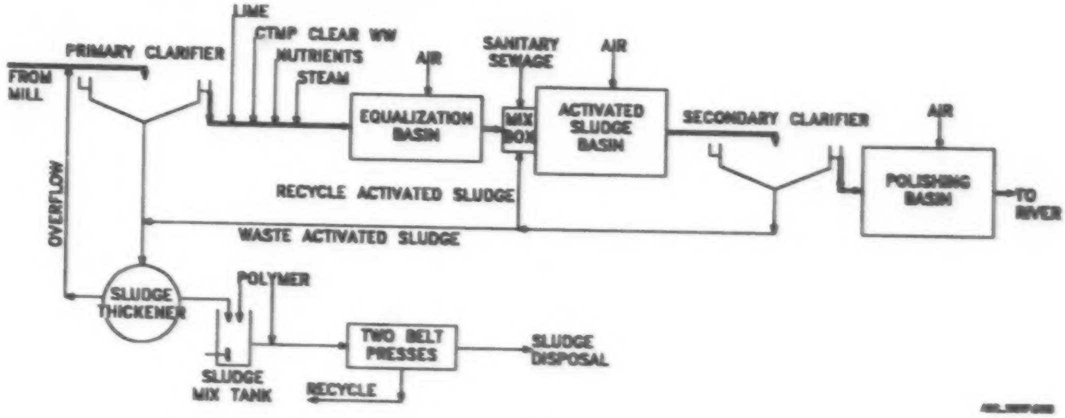

LIME
CTMP CLEAR WW
NUTRIENTS
STEAM
PRIMARY CLARIFIER
FROM MILL
AIR
SANITARY SEWAGE
AIR
EQUALIZATION BASIN
MIX BOX
ACTIVATED SLUDGE BASIN
SECONDARY CLARIFIER
AIR
POLISHING BASIN
TO RIVER
OVERFLOW
RECYCLE ACTIVATED SLUDGE
WASTE ACTIVATED SLUDGE
SLUDGE THICKENER
POLYMER
TWO BELT PRESSES
SLUDGE DISPOSAL
SLUDGE MIX TANK
RECYCLE

Figure C.12 Alberta Newsprint, Whitecourt, Effluent treatment

Drawn by N. McCubbin Consultants Inc. from information provided by Alberta Environment

Summary data on the mill effluent for three winter months are shown in Table C.0. These data were extracted from mill reports to Alberta Environment. Daily BOD and TSS discharges for a full winter are shown in Figures C.13 and C.14. These BOD and suspended solids discharges are exceptionally low relative to most historical data from other activated sludge systems in the pulp and paper industry.

The treatment system is obviously well designed and operated. The capital cost of the system was reported to be approximately $15 million in 1990, which is modest for the influent BOD load mentioned in Table C.0.

Table C.1 Alberta Newsprint, Whitecourt, Effluent treatment

Design data		
Effluent flow	15,000 m^3/day.	
Retention time in aeration basin	2.5 days	
Sludge retention time	10-12 days	
MLSS	3,000 mg/L	
Food:microorganism ratio (F:M)	0.20	
Influent BOD	21,000 kg/day (avg)	28,000 kg/day (max)

Regulatory requirements at low river flows	**Maximum monthly average (kg/day)**	**Typical discharges (kg/day) 1990/1991**
BOD	1,650	150
TSS	6,650	300
Colour	31,500	3,525
	Maximum daily discharge (kg)	**(kg)**
BOD	3,300	630
TSS	13,000	1,950
Colour	42,000	6,540

Source: Data from Alberta Environment

Acute lethality to trout and *Daphnia magna* are verified approximately once per month. The Alberta Environment records show that effluent LC_{50} has been >100% on all occasions from the mills start-up in July 1990 until June 1991 (latest data available to the authors). Mill staff reported that there had been no fish mortality in the acute lethality tests.

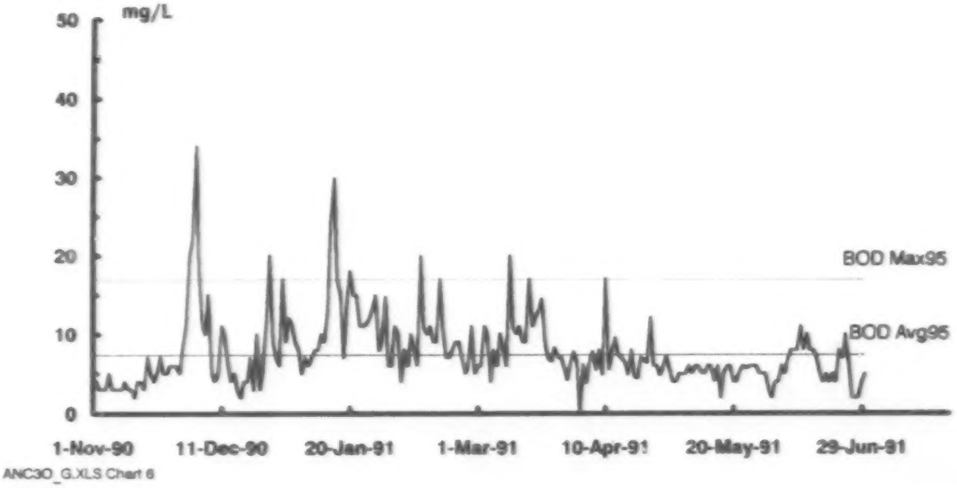


Figure C.13 Alberta Newsprint, Whitecourt, Effluent BOD

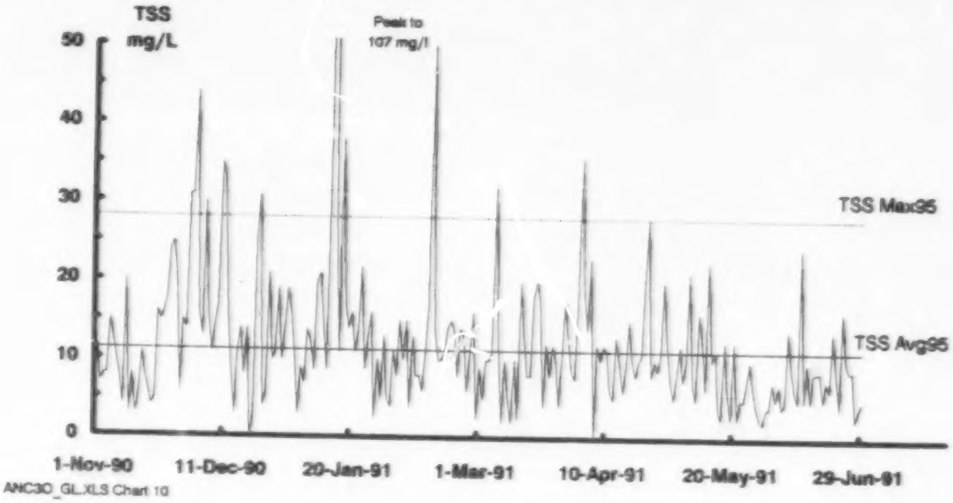


Figure C.14 Alberta Newsprint, Whitecourt, Effluent TSS

The discharges of phosphorus and nitrogen are shown in Figure C.15.

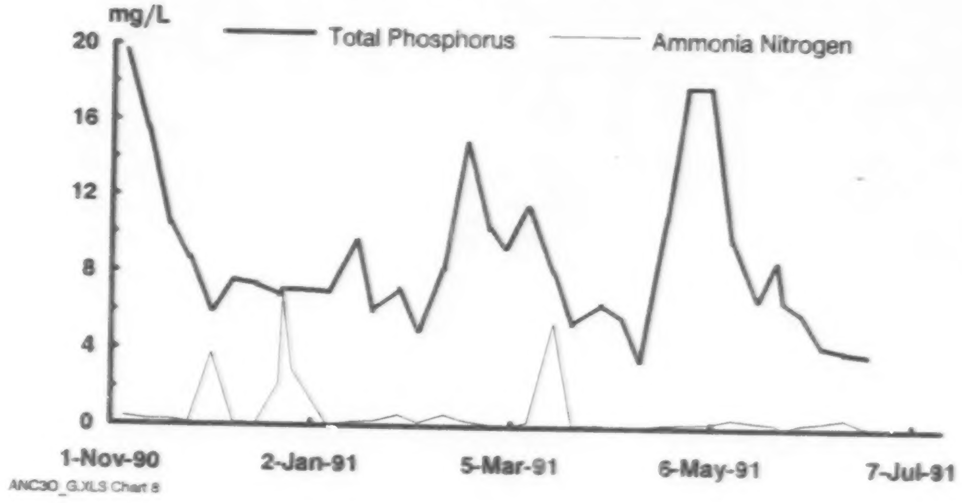
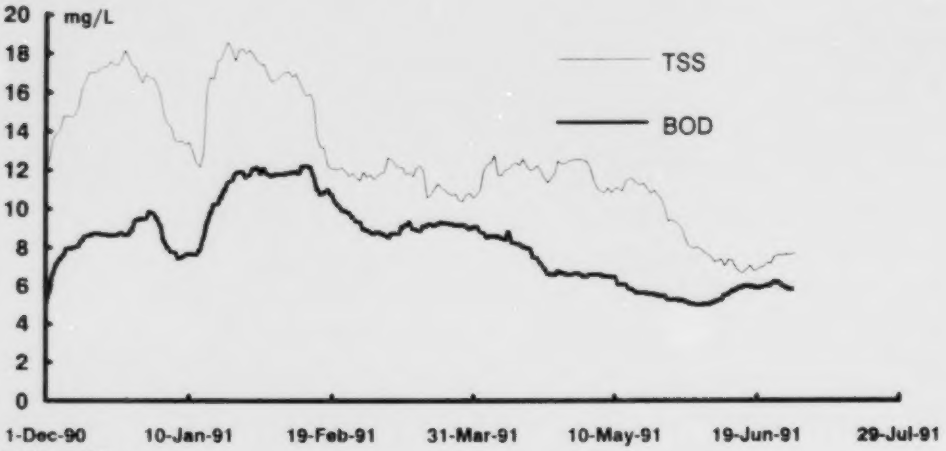


Figure C.15 Alberta Newsprint, Whitecourt, daily nutrient discharges

The phosphorus discharge would be considered to be unacceptably high for most Ontario mills. ANC mill staff have advised that their prime objective in the initial several months of operation was to make sure they complied with all regulations at all times, so they adjusted the nutrient charge to the plant to promote maximum BOD removal. There is no doubt that the plant will operate well at lower rates, but some time and experience will be required to determine the practical minimum nutrient discharge rate. In the authors' experience, some trade-off between nutrient discharge and the discharge rates of BOD and TSS will probably be necessary.

This plant demonstrates that there is no simple definition of "best" effluent treatment technology. In some receiving waters or regulatory environments, low BOD discharge would take precedence over low nutrient discharge, and in some, vice versa.



ANC3O_G.XLS Chart 7

Figure C.16 Alberta Newsprint, Whitecourt, BOD and TSS AVG$_{30}$

Diashowa, Peace River, Alberta

Diashowa Canada operates a 1000 tonne/day market kraft mill at Peace River, in North Western Alberta. The mill commenced production in mid 1990, and had not yet reached full production at the time of writing.

The process equipment consists of a single fibre line, with dry debarking, a continuous digester equipped for extended cooking, oxygen delignification and a high-substitution bleach plant. The mill manufactures both softwood and hardwood pulps, with changes in wood furnish according to customer demands. The periods of softwood production are indicated on the graphs below.

There is a spill recovery system in the recovery boiler and evaporator areas to recover accidental losses of black liquor. There is also a spill basin to which the total mill effluent flow can be diverted to prevent major spills reaching the biological treatment system. The automatic control system is based on conductivity.

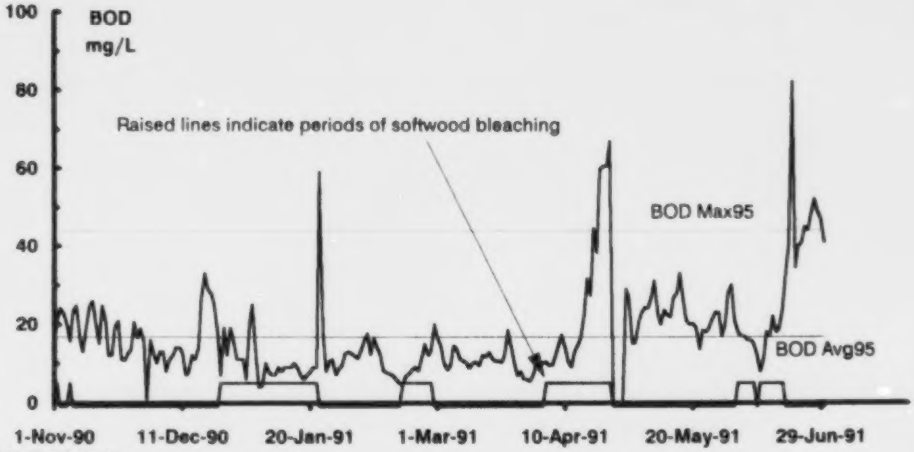
After primary treatment, the effluent is stabilized in a single cell ASB of 600,000 m^3 capacity. This corresponds to about 9 days retention time at the average effluent flows for the period reported in the graphs below. The design retention time is 11 to 12 days. The aeration system uses submerged jets, instead of the more conventional surface aerators.

The effluent discharge requirements are a maximum of 7.5 kg/tonne BOD, 9 kg/tonne TSS, and 1.4 kg/tonne AOX. The effluent is required to be non-lethal to trout.

Design effluent flow is 55 m^3/tonne, but actual operating flows have been up to 150 m^3/tonne, with an average of 96 m^3/tonne. This value appears to be dropping as mill production increases with operating experience.

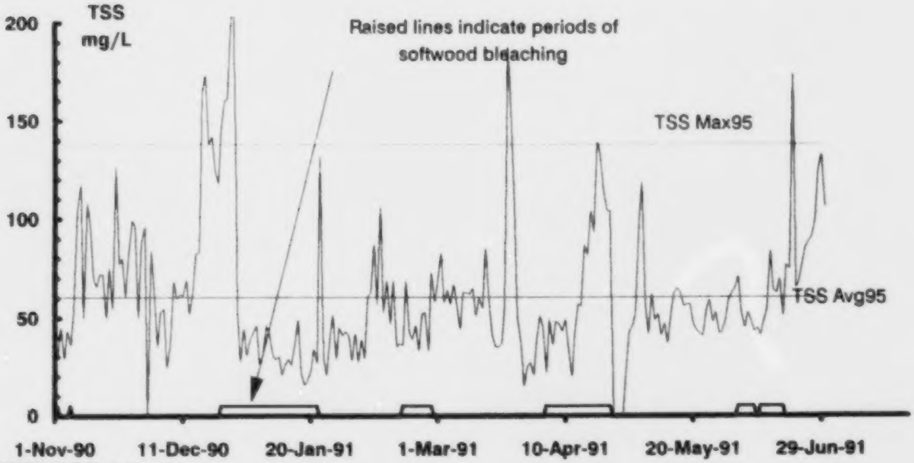
Effluent treatment

BOD and TSS discharge concentrations from November 1990 until mid 1991 are shown in Figures C.17 and C.18. These correspond to average discharges of 1.6 and 5.7 kg/tonne product respectively. There is no apparent correlation between BOD, or TSS in the treated effluents and the wood furnish.



PEACE3OG.XLS Chart 6

Figure C.17 Diashowa, Peace River, Effluent BOD



PEACE3OGL.XLS Chart 10

Figure C.18 Diashowa, Peace River, Effluent TSS

The rolling 30 day average BOD and TSS discharge concentrations are shown in Figure C.19. The maximum monthly average concentrations would be as shown, in the worst case. In practice, it is unlikely that the calendar month would coincide with the highest 30 day period.

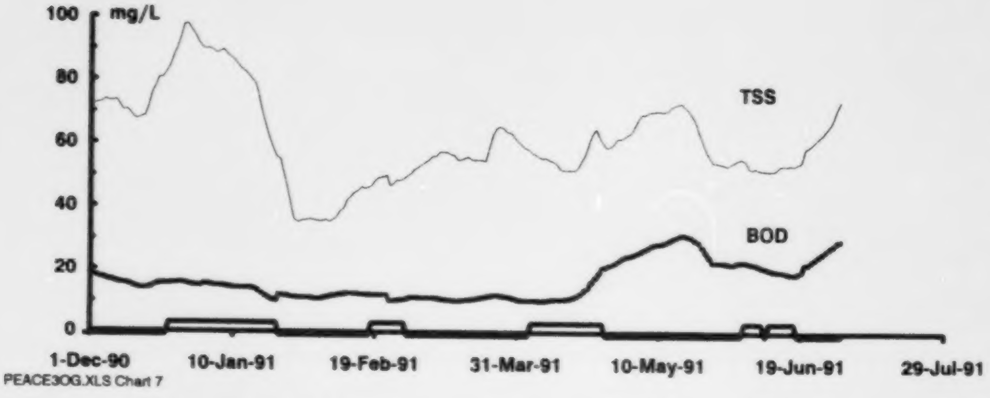


Figure C.19 Diashowa, Peace River, Monthly average BOD and TSS concentrations

None of the data on BOD and TSS discharges exhibit the seasonal variation traditionally expected with ASB treatment systems in cold climates.

The AOX discharges are shown in Figure C.20. The data are expressed in kg/tonne product, because that is the conventional way of presenting AOX information. The mill production has been somewhat erratic, since the initial start-up was in late 1990. The long retention effluent treatment system makes it impossible to attribute AOX discharges to any one production day, so the basis for calculating these production based loadings was the average of the previous ten days saleable production.

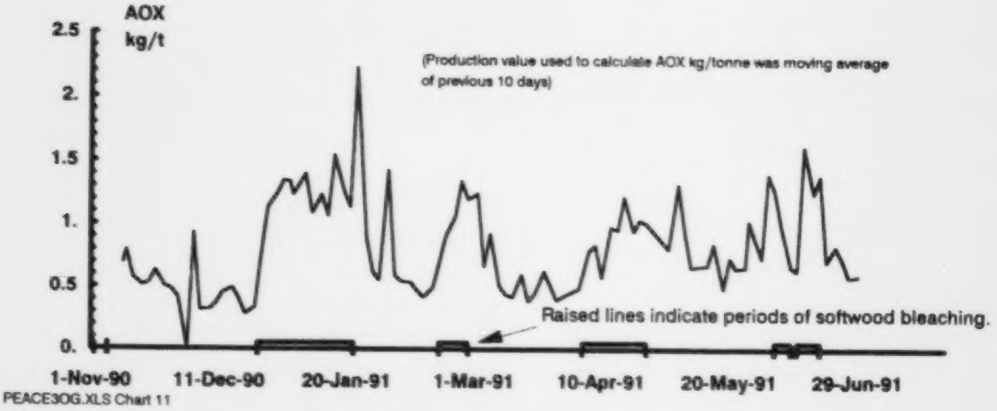


Figure C.20 Diashowa, Peace River, AOX discharges

The AOX discharges appear to be perhaps somewhat lower when hardwood is being pulped, which would be in accordance with experience elsewhere. However, the effects of biological treatment and the mixing in the relatively long retention ASB appear to be almost eliminating the hardwood/softwood difference. There does not appear to be any seasonal variation in AOX discharges.

Ponderay Newsprint, Usk, Washington

The Ponderay Newsprint mill at Usk, Washington is designed to produce 500 tonnes per day of newsprint. It is based on the CTMP pulping process which involves addition of sodium sulphite in either of the different process variations. In one variation the chips are steamed in a vessel containing a 3% to 6% sulphite solution for approximately one hour and then refined. In the other, the chips are steamed alone then pressed and soaked in a tank containing sodium sulphite solution en route to refining.

The chemical pretreatment of the chips results in an untreated CTMP effluent containing sulphites in the range of 500 to 1500 mg/L, averaging 750 mg/L.. Approximately 10% to 26% of the measured BOD is also due to residual sulphite. Similar high sulphite concentrations have been reported to upset the success of biological treatment systems in Canadian mills. There are no CTMP mills operating in Ontario at the time of writing, but one could perhaps expect comparable problems in the high yield sulphite mills. This concern was alleviated by providing physical-chemical treatment prior to the main biological treatment aeration basin. The physical-chemical treatment of the concentrated stream from the CTMP precipitated 75% or more of the unspent sulphites. Mill operating experience has demonstrated that the high sulphite concentrations will not interfere with biological treatment providing that suitable provisions are incorporated into the design (Reeser 1989a).

Extensive data are available in the Washington State files (Ray 1991) concerning the Ponderay, Usk mill. Further papers describing the effluent treatment plant research and its environmental permits have been presented by Reeser (1989a, 1989b). Bennet (1991) described research to reduce toxicity at the Ponderay, Usk mill.

BOD and TSS final effluent concentration data are summarized in Table C.2. The mill production during this time period averaged approximately 515 tonne per day. The January, 1990 data were collected during start-up and may not be representative of normal operating conditions according to Roger Ray of the Washington State Department of Ecology, Spokane, WA office. He is the regulatory individual responsible for monitoring discharges from the Ponderay, Usk mill.

Table C.2 Ponderay mill, Usk, Effluent characteristics

Month	BOD average	BOD maximum	TSS average	TSS maximum
January	43	116.5	107	584
February	25	45	44	71
March	23	53	53	152
April	8	20	11	27
May	6	29	13	47
June	9	19	13	23
July	10	31	26	265
August	7	18	14	91
September	7	13	9	26
October	15	35	14	31
November	27	73	18	38
December	21	71	35	295

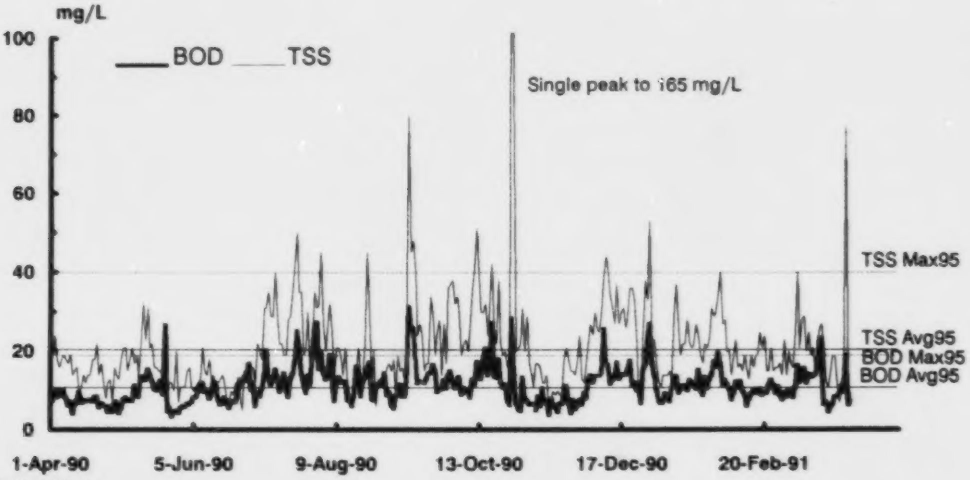
"Maximum" implies highest value of daily samples
All data expressed as mg/L.
Source: mill reports

The pulp mill has taken production curtailments during the past year for periods of approximately 4 to 5 days due to market conditions. During the mill shutdowns a starch substrate has been fed to the effluent treatment plant to maintain the desired microbiological population. This has prevented performance upsets when the mill resumed production, that were otherwise anticipated.

The Usk system uses an oxidation ditch, as described in Appendix G.

Champion International, Canton, North Carolina

The mill was constructed at the turn of the century, and currently produces 1200 tonne per day bleached kraft pulp, primarily for use on site in a variety of paper machines manufacturing a variety of products including milk carton stock and fine papers. A conventional activated sludge plant was installed during the 1960's. This reduces the final effluent to below 20 mg/L BOD and TSS to below 40 mg/L. The final effluent discharge is approximately 170,000 m³/day, equivalent to about 140 m³/tonne pulp. The typical long term influent BOD is about 73,000 kg/day (425 mg/L) with greater than 95% BOD removal being realized. The pulp mill and recovery boiler areas are currently being modernized, but the effluent data represents the performance of a very old mill. The effluent quality is summarized in Figure C.21.

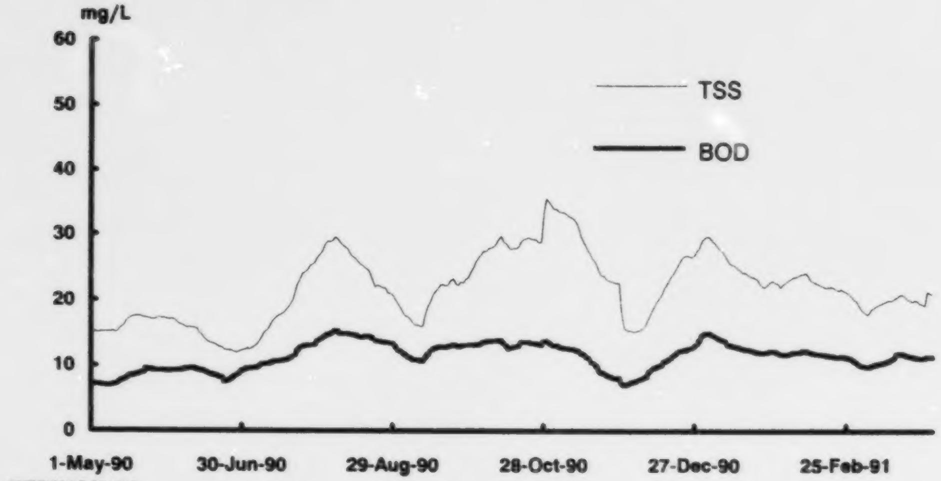


CANTON.XLS Chart 4

Figure C.21 Champion, Canton, NC, Effluent BOD and TSS

When one of the author's visited this mill, it was evident that extremely high attention was paid to the effluent quality. The effluent treatment plant itself is quite well instrumented, and has an excellent data logging and reporting system supplemented by extensive analysis of the operations by the operators and process engineers. The age of the mill and lack of a modern spill control system places high demands on the effluent treatment system and its operation. The authors estimated that approximately 125 man hours/day were spent on operation and routine maintenance of the effluent treatment system, including constant co-ordination with the mill operators to minimize spills. This is about double the manpower normally required to attain a high level of performance in a more modern installation protected by an effective spill control system.

The rolling averages of the BOD and TSS discharges are shown below.



ANTON.XLS Chart 6

Figure C.22 Champion, Canton, NC, BOD and TSS discharges, 30-day rolling average

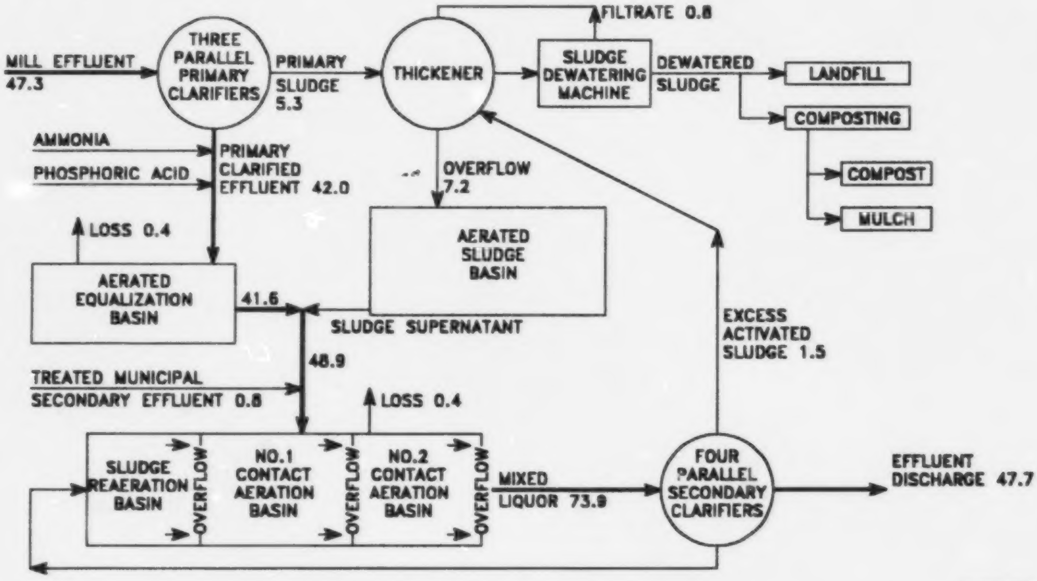
P.H. Glatfelter, Spring Grove, Pennsylvania

The P.H. Glatfelter Paper Company at Spring Grove, Pennsylvania operates an activated sludge system which has exhibited excellent performance for many years. The mill produces approximately 550 tonnes/day bleached hardwood and softwood kraft pulp, which is used in the integrated paper mill. The latter manufactures 720 tonnes/day of a wide variety of coated and uncoated fine papers on 7 paper machines.

The effluent treatment system processes an average of 47,000 m³/day of pulp and paper wastewater. Refer to Figure C.23.

Primary treatment

The primary influent is neutralized to a pH range of 6 to 8 using scrubber water from the lime kiln and spent sulfuric acid from the chlorine dioxide generating plant. Primary treatment is carried out in three clarifiers operating in parallel. These provide a three hour retention time and overall suspended solids removal is normally in the 70% to 75% range. The combined primary sludge is pumped to the gravity thickener at the sludge dewatering facility.


FILTRATE 0.8
MILL EFFLUENT 47.3
THREE PARALLEL PRIMARY CLARIFIERS
PRIMARY SLUDGE 5.3
THICKENER
SLUDGE DEWATERING MACHINE
DEWATERED SLUDGE
LANDFILL
COMPOSTING
COMPOST
MULCH
AMMONIA
PHOSPHORIC ACID
PRIMARY CLARIFIED EFFLUENT 42.0
OVERFLOW 7.2
LOSS 0.4
AERATED SLUDGE BASIN
AERATED EQUALIZATION BASIN
41.6
SLUDGE SUPERNATANT
EXCESS ACTIVATED SLUDGE 1.5
48.9
TREATED MUNICIPAL SECONDARY EFFLUENT 0.8
LOSS 0.4
SLUDGE REAERATION BASIN
OVERFLOW
NO.1 CONTACT AERATION BASIN
OVERFLOW
NO.2 CONTACT AERATION BASIN
OVERFLOW
MIXED LIQUOR 73.9
FOUR PARALLEL SECONDARY CLARIFIERS
EFFLUENT DISCHARGE 47.7

VALUES SHOWN ARE 1000 CUBIC METERS PER DAY

Figure C.23 Glatfelter, Spring Grove, Effluent treatment system flowsheet

Secondary treatment

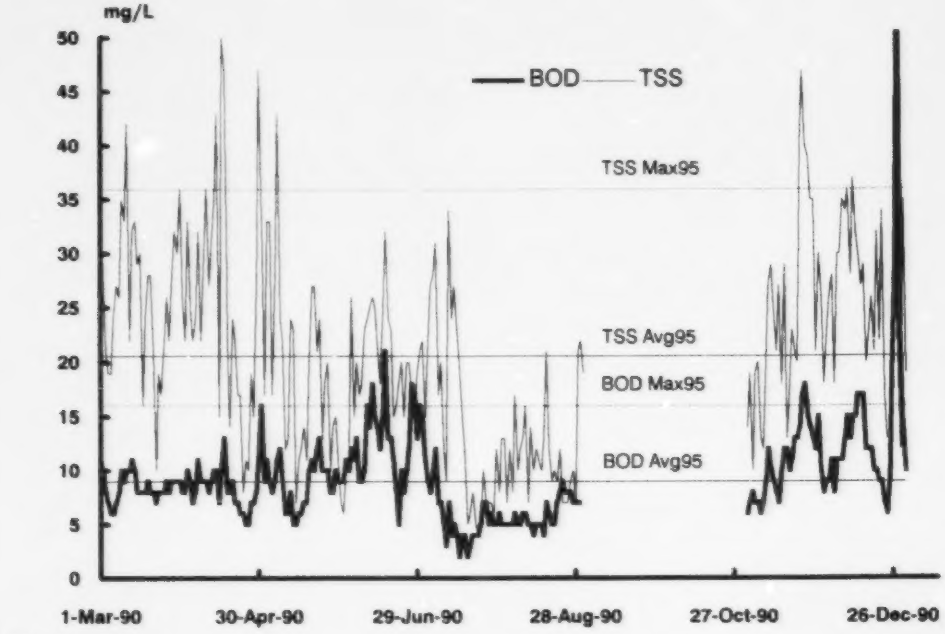
Anhydrous ammonia and phosphoric acid are added to the primary clarified effluent as required to maintain proper nitrogen and phosphorus levels for the bacteria in the secondary plant. The nutrients are added on the basis of average mill effluent flow, BOD_5 loading, residual in the secondary effluent discharge and historical experience.

The contact stabilization activated sludge secondary treatment plant consists of three aeration basins in series. One is a stabilizer for aeration of return sludge, while the other two are contact basins in series for aeration of the mixed liquor. Aeration in the latter is provided by flat-blade, two-speed turbine-type surface-entrainment aerators arranged as follows: 9 at 60 HP in the No 1 aeration basin and 5 at 60 HP in the No 2 aeration basin. Aeration in the stabilizer was converted in 1975 from turbine surface-entrainment type to a low pressure air static aeration system. Involved are three two-speed blowers at 75 HP delivering a maximum of 3400 m^3/hour each at 45 kPa to 240 static aerators.

Settled activated sludge is pumped at a controlled rate from the bottom of the secondary clarifiers to the stabilizer. The returned sludge is aerated and then overflows a level control structure into the first aeration basin where it is mixed with the incoming primary effluent plus the sludge thickener overflow. The latter flow passes through an aeration lagoon prior to mixing with the primary effluent to form the combined secondary influent.

The mixed liquor in the first aeration basin is aerated and allowed to overflow a level control structure into the second aeration basin, followed by a similar overflow from No 2 aeration basin to a distribution box. For a 50,000 m^3/day average mill effluent flow and a 50% recycle of activated sludge, the stabilizer provides three hours retention for return sludge aeration, while the two aeration basins combined allow for 3.3 hours aeration of the mixed liquor. An equalizing basin proceeding activated sludge was installed during the 1980s.

The Glatfelter treatment system is well known for having a track record of excellent performance. The data on its operation in 1990 which were available from the files of the Pennsylvania Department of Environmental Resources are summarized in Figure C.24. Data were not available for August 28 to October 27, 1990.



GLATFELD.XLS Chart 3

Figure C.24 Glatfelter, Spring Grove, BOD and TSS discharges

Discharges of phosphorus from this system are exceptionally low, as indicated in Figure C.25. These data have withstood the scrutiny of several professionals, including those from the the US EPA.

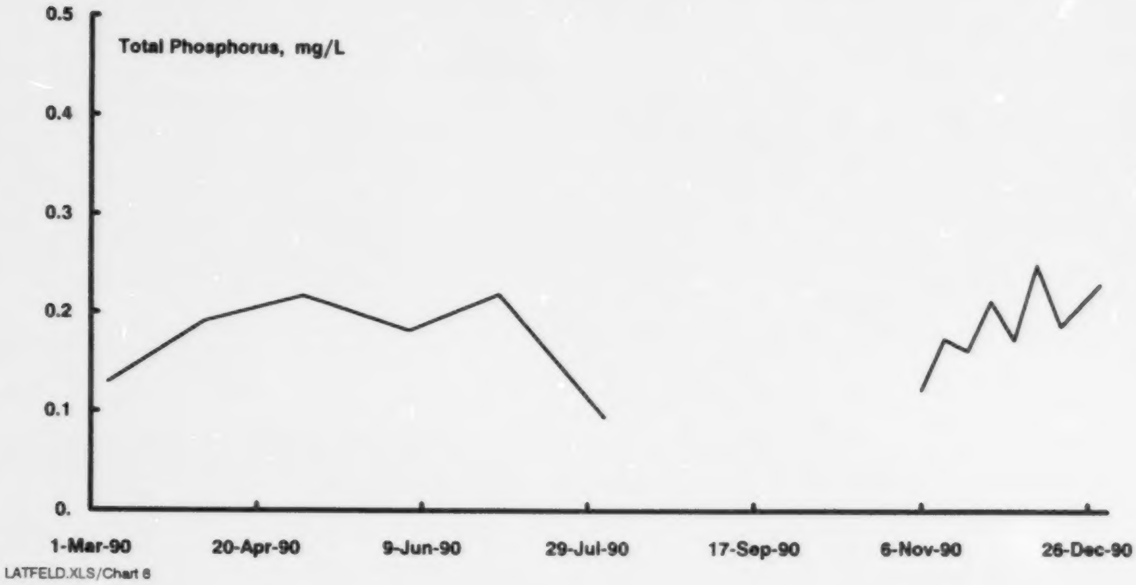


Figure C.25 Glatfelter, Spring Grove, Total phosphorus, daily discharges.

Union Camp Corp., Franklin, Virginia

Personnel:

Wells E. Nutt, President, Union Camp Technology Inc
Norman C. Shroyer, Technical Director, Franklin Mill

Purposes of visit

Review technology and commercial status of the chlorine-free bleach plant under construction by Union Camp.

Determine whether this should be considered as proven technology as defined by the Ministry of the Environment, and discussed in the body of the report.

Establish capital and operating costs (Detailed data were not available).

Establish commercial availability of chlorine free bleaching processes from Union Camp Technology Inc.

Background

Union Camp Corp (U-C) has four kraft mills and various other forest products operations. The company's two bleached kraft mills produce a total of slightly over one million tonnes/year bleached kraft pulp, or about 55% of Ontario's bleached kraft pulp production. U-C is a 100 year old US corporation that has been manufacturing pulp and paper since 1937 at Franklin. 1990 sales were US$2.8 billion.

The Franklin mill is fully integrated, and all pulp is bleached for manufacture of fine paper on site. The company's other bleached kraft mill, at Eastover SC manufactures bleached market kraft pulp with two bleach lines, both OCdEDED.

U-C research division has had an active research program directed toward replacement of chlorine in bleaching for about ten years, with as many as 40 dedicated staff on the project at times. They concluded that ozone delignification following oxygen delignification was the best approach. In 1987 they built a 25 tonne/day pilot ozone bleaching system in their Eastover SC mill. This unit is fed by oxygen delignified softwood (southern pine) and hardwood (mixed southern) from the mill production line, and the ozone delignified pulp is returned to the main production line.

In June 1990 U-C announced the investment of $158 million in a new 900 tonne/day[2] bleach plant at their Franklin mill, to replace two 40 year old conventional design bleach plants which use the CEDED sequence.

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[2] *UC announcements are generally in US units. The authors have converted to the SI system used in this report where appropriate.*

The new plant will use the OZED bleaching sequence to eliminate the use of chlorine and reduce the use of chlorine dioxide. U-C will marked the associated bleaching know-how under the name "C-FREE".

The authors were the first group other than potential customers to receive approval from the company for the Union Camp Technology Incorporated to release cost and performance information. This information is covered by the normal requirements of protecting valuable commercial and technical information.

Ozone delignification process

The new bleach plant at Franklin is designed to bleach 900 tonne/day southern pine kraft pulp to at least 85 ISO brightness for use by the fine paper machines on site. There will not be any market pulp production. The process flowsheet is considered confidential. The batch digesters will continue as the source of pulp, and there are no plans to install extended cooking technology as sold by Sunds Inc. and Beloit Inc.

Pulp washing will be counter-current from the ozone stage washer, through the oxygen stage, to the brownstock washers to the recovery boiler. All the organics released in delignification up to and including the ozone and extraction stages will be destroyed in the recovery boiler, and the sodium hydroxide from the pre-bleaching stages will be recovered. This will represent about 9% more organic loading on the recovery boiler and an increased load on the recausticising and lime kiln areas than in a conventionally designed mill. Refer also to the discussion of ozone bleach plant mass balances in Chapter 6.

Ozone will be generated on site by a commercially available ozone generator. The design of the ozone reactor and of the system for ozone reactor vent gas cleanup and recovery is considered proprietary by U-C. Know-how on process control and operating strategy is also proprietary and will be available only to licensees. The remainder of the bleach plant will follow conventional design for a modern bleach plant preceded by oxygen delignification.

U-C recommend that high consistency oxygen delignification be used rather than the more popular medium consistency systems, since greater kappa number reductions are attainable prior to the ozone stage. However, they are prepared to guarantee the C-FREE process with either medium or high consistency oxygen delignification preceding it.

U-C agreed that the use of extended delignification to further lower incoming kappa numbers was desirable.

U-C is not prepared to release mass and energy balance data, but have presented the data in Table C.3 on chemical costs and effluent characteristics for conventional compared with C-FREE processes. The large difference between conventional and OZED bleaching costs would be much less if the conventional system was operating according to the normal practices prior to the discovery and concern about dioxins.

Table C.3 Union Camp, Franklin, Comparison of conventional and C-FREE bleaching

	Units	CEDED	$OCD_{30}ED$	OZED
Bleach plant effluent flow	m^3/tonne pulp	47	16	14
Southern pine pulp to 82 ISO brightness				
TOX in pulp	kg/t pulp	0.28	0.13	0.04
TOX in bleach plant effluent	kg/t pulp	6.5	3.0	0.08 *
Chloroform generation	kg/t pulp	0.18	0.08	0.002
BOD in bleach plant effluent	kg/t pulp	16	7	1
Colour (APHA chloroplatinate)	kg/t pulp	185	42	1.5
Breaking length	km	13.8	12.4	12.3
Viscosity		17	13	11
Tear	dm^2	111	119	124
Bleaching chemical cost **	$US/tonne	50	33	17
Mixed southern hardwoods to 82 ISO brightness				
TOX in pulp	kg/t pulp	0.2	0.12	0.03
TOX in bleach plant effluent	kg/t pulp	3.0	2.0	0.06 *
Chloroform generation	kg/t pulp	0.18	0.1	0.002
BOD in bleach plant effluent	kg/t pulp	8	4.5	1
Colour (APHA chloroplatinate)	kg/t pulp	55	12	0.5

* Depends on amount of chlorine in chlorine dioxide

** At typical US costs, assuming current dioxin control measures have been implemented Ontario chemical prices differ, but are in the same order of magnitude

Source: Union Camp

The data in Table C.3 are based on bleaching kraft pulp to 82 ISO brightness, since this is the requirement for the paper machine feedstock at Franklin. Mills manufacturing market pulp would have to attain about 90 ISO brightness, depending on specific customer requirements. U-C advised that the ceiling brightness for the OZED sequence has been found to be 86 ISO in tests. They have some reasonable and acceptable modifications to produce market pulp.

U-C have no explanation for the much greater reduction in colour than in total organic discharge shown in Table C.3, beyond the generally known fact that the final chlorine dioxide bleaching stages operate primarily by substitution of chromophores, rather than by dissolving lignin as occurs in earlier stages of bleaching.

Effluents

The Franklin mill has a rather unique effluent discharge permit, since no discharge whatsoever is permitted from 1st May till 31st October each year, and a stringent recipient dissolved oxygen standard must be respected while discharging during the winter period. The river is unusually small for a kraft mill recipient, with a minimum monthly average flow of 20 m^3/second.

The mill has a conventional primary treatment system followed by an aerated stabilization basin which is reported to remove 50% of AOX. The average effluent flow is 63 m^3/t finished paper Annual average permitted discharges and actual discharges are shown in Table C.4.

The low BOD and TSS discharges are probably due in part to the oxidation of organics in the storage basins which must hold at least 6 months effluent.

Table C.4 Union Camp, Franklin, Treated effluent discharges

	Permitted kg/day	Actual kg/day	Actual kg/t paper
BOD	5500	1250	0.74
TSS	16,800	2500	1.5

* Calculated by authors, from nominal production of 1700 tonne/day
US units converted to SI and rounded by author

The mill effluent routinely passes an acute lethality test with bullhead minnow as the test organism.

Effluent samples were inspected during the visit that supported the colour reduction to the extent that colour could be visually evaluated.

Commercial status of C-FREE

Union Camp Technology Incorporated was formed in 1991 to market and support the "C-FREE" technology, and is a wholly owned subsidiary of Union Camp Inc. C-FREE refers to the ozone based kraft pulp bleaching technology being developed by U-C and discussed in this mill visit report.

Union Camp and Sunds Defibrator[3] announced a marketing alliance in March 1991 to provide equipment, technology and technical support for the C-FREE process. They are currently prepared to sign supply contracts with pulp and paper companies, but had not yet done so at the time of the author's visit.

The U-C pilot plant is available for testing customer's pulps to minimize engineering uncertainties, and U-C support will include training of customer's operators at their Franklin plant.

Conclusions

The data available on the C-FREE process indicate that it is technically capable of producing fully bleached kraft pulp, while discharging lower quantities of organochlorines, BOD and colour, than any currently proven process for bleaching kraft pulp. The data presented by U-C is consistent with laboratory data published by independent researchers. However the C-FREE process has not yet been proven on a commercial scale or supported by publicly available data, so it cannot be considered as "proven technology" as defined in the mandate for this report.

The extent of research and the commitment of US$158 million to construct the 900 tonne/day bleaching line at Franklin demonstrates that the process merits serious consideration as a means of improving effluent quality, and could be adopted by some Ontario companies to comply with the pending Ministry of the environment regulations. Full scale data on operations and effluent quality should be available in late 1992. There is no possibility of full-scale data being available before September 1992, so that the earliest that a full year of data could be available would be September 1993.

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[3] *A major manufacturer of pulp bleaching and mechanical pulping equipment, based in Sweden, but also well established in North America. Sunds have provided approximately 70% of the 20 oxygen delignification systems in North America, including 5 in Canada, and will furnish the principal process equipment for the ozone bleach system at Franklin.*

U-C consider much of their technology to be proprietary, so that independent confirmation of their research conclusions will be available only to licensees. If several kraft pulp manufacturers elect to become licensees, install the C-FREE process full scale, and assume the related financial commitments, then the associated commitments to the regulatory authorities could perhaps provide the necessary independent confirmation of the feasibility and performance of the C-FREE process before September 1993.

Aspa, Sweden

The Munksjö mill at Aspa produces market kraft pulp, and is of particular interest because of extensive studies and full scale trials carried out over the past few years on alternative means of reducing organochlorines. The results of these studies have been made public, and aspects of interest to Ontario mills are summarized below.

Aspa Bruk[4] has a unique full-scale pilot bleaching system to manufacture chlorine-compound-free semi-bleached kraft pulp. The mill management would not permit a visit by the project team, as they consider that their manufacturing know-how is a competitive advantage. The following information was collected from data in the public domain, principally in the hands of the Swedish regulatory authorities. (Refer also to comments on the Lignox process in Chapter 6 of the report).

Munksjö Aspa Bruk is situated at the Northern part of Lake Vättern and produces softwood kraft pulp through continuous cooking (360 tonnes per day). In 1988 they changed their bleach sequence from O ($C_{85}D_{15}$) (EP) D (EP) D to O ($C_{75}D_{25}$) (EOP) D (EP) D, and their current permit allows the mill to continue this operation. They have a permit to discharge 3.0 kg TOCl[5] per tonne pulp from July 1989 which must be reduced to 1.5 kg TOCl per tonne pulp by January 1992. The effluent is treated in a primary clarifier, but there is no biological treatment. At the time of the contact, the company had no plans for installing secondary treatment in the near future. Table C.5 summarizes the 1990 data for Aspa Bruk, as reported to the Swedish regulatory authorities.

Table C.5 Aspa Bruk, Effluent data , 1990

	Tonne/year	Tonne/day	Kg/tonne
Production			
Bleached kraft	94,586		
Lignox pulp 150 70	9,372		
Unbleached kraft	8,408		
Kappa 29			
Process water (m^3)		39,567	117
COD	5,100	16	46
BOD_7	1,590	4.8	14.2
TSS[6]	319	0.96	2.8
AOX	201	0.61	2.1
Tot-N	19	0.057	0.168
Tot-P	5	0.015	0.044

A dioxin analyses from 1988 did not reveal any content (<0.6 ppt TCDD (Eadon, refer to TEQ table in Chapter 4)).
332 operating days. Source: Data reported to Swedish regulatory authorities. (Lensstyrelsen).

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[4] *"Bruk" is Swedish for mill, and appears frequently as part of mill names.*

[5] *TOCl or Total Organically bound Chlorine was one of the earlier ways of quantifying the organochlorine content of pulp mill wastes. It has largely been supplanted by the AOX analysis which is used in Ontario and most of North America. There is no absolute correlation between these methods, but it is reasonable to assume that the measured AOX concentration of a sample will be about 20% higher than the TOCl (Bonsor 1988, p 176).*

[6] *TSS_{70} is suspended material, that will be caught in a 70 um wire filter (not to be confused with the TSS_{GFC} procedure universal in North America, which would give substantially higher results for the same effluent sample)*

Lignox

The *Lignox* process was developed by EKA-Nobel, a major supplier of technology and chemicals to the pulp and paper industry. The authors of this report recognize that EKA, or associated organizations, are proprietors of the process, and the description herein is purely for readers information. Refer to Chapter 6 in the body of the report for a typical flowsheet and general process description.

Aspa Bruk is presently running the *Lignox* plant on an experimental basis, in that they did not have the operation permit at the time of writing (March 1991). Aspa Bruk is continuously working on quality and economy improvements, especially improved delignification in the first EP-stage by increased retention time and with a higher consistency.

Other processes investigated

The Aspa mill is an excellent source of information on current Swedish technology, since extensive studies on alternative ways of protecting the local receiving waters have been undertaken and the results published. The information relevant to Ontario is summarized below

Prenox

Munksjö Aspa Bruk has evaluated the possible use of the Prenox process in a 500 tonnes per day plant. This would allow the operation of their oxygen delignification system to produce a lower Kappa number pulp than at present . Capital costs were estimated to be $40 million. Operating costs were estimated to be $16/tonne. They estimated a design and construction period of 24 to 30 months followed by an implementation period of 36 to 42 months at the cost of $2 million.

The predicted effect on the effluent was a reduction in TOCl from 1.5 to 1.0 kg/tonne. Biological treatment could further reduce the TOCl below 0.5 kg/tonne. The Munksjö Aspa Bruk considers the Prenox process technically risky and financially unattractive. (Munksjö Aspa Bruk, 1990-05-15, Appendix 2.)

100 % ClO_2 substitution

A number of full-scale experiments have been conducted between May 88 and February. 90 substituting 100% chlorine with chlorine dioxide. The results showed a significantly increased demand for active chlorine from 50 to 55 kg/tonne to 65 kg/tonne pulp. These experiments were conducted for periods of under 24 hours due to the limited capacity of the chlorine dioxide plant.

When the Kappa number of the oxygen delignified pulp entering the bleach plant is 18 the increased costs of operation amount to approximately $20/tonne. If the Kappa number of the incoming pulp is above 18 then a fully bleached pulp could not be achieved. (Many North American mills successfully produce fully bleached market kraft pulp using 100% substitution of chlorine by chlorine dioxide, even when the Kappa number of the incoming pulp is over 30. Presumably the failure at Aspa Bruk was due to equipment limitations)

The AOX level after this was slightly above 1 kg/tonne (a reduction of approximately 0.5 kg/tonne), but the chlorate discharge increased to approximately 7 kg/tonne.

The effect of 100% chlorine dioxide substitution on the COD level was insignificant.

Extended cooking

Lower Kappa numbers which can be achieved by the implementation of extended cooking technology without affecting the pulp strength would be desirable. A retrofit at Aspa has been estimated to cost around $4 million. However, the length/diameter ratio of the digester is relatively high at Aspa, which could make it very difficult to modify successfully, so this relatively low estimate must be questioned. (The authors of this report concluded that the only technically proven means of attaining the maximum benefits from modern extended cooking technology is to install a new digester). Munksjö is considering other approaches.

Ultrafiltration

The principle would be to install ultrafiltration on the E_1 bleach plant effluent, and recycle the filtrate to the evaporator system and eventually incinerate the chlorine containing material in the recovery boiler. Such a system was installed at the MoDo mill at Husum, Sweden in 1988 on a softwood bleaching line. It consisted of 4 CR-1000 filters (ABB Water Filtration of a capacity of 50 m^3 each). The filtrate is burned in the recovery boiler. The flux is 200 to 250 L/m^2 and the efficiency of AOX and COD removal is 50% to 60% (200 m^2 of polysulfon membranes with cut-off at Mm 25,000). At Husum they do not consider this to be commercially acceptable yet, but they expect the system to be so in the near future. The key problem is the cost of membrane replacement. Initially they had difficulties with membrane stability. They feel that they have solved most of those problems and now they expect an operating time of two years between membrane changes. They had to install facilities for membrane back-wash during operation as membranes tended to plug. They also had to implement a water conservation program for the bleach plant in order to reduce the amount of water to be treated.

Capital costs for such a system at Aspa have been estimated to be $8 million; operating costs have not been estimated.

The effect on AOX discharge would depend on the starting level. If this level is high, as in the case of MoDo Husum, a significant reduction can be expected, whereas a low starting level, as in the case of Aspa Bruk, may result in only minor reductions. The COD discharge from the stream concerned may be halved.

At Aspa, the recovery boiler does not have corrosion resistant materials in the furnace and there is no scrubber installed for HCl recovery. In addition, AOX discharges were already low, so this option was not considered further.

Chemically aided coagulation

Coagulation agents, such as alum, may reduce AOX by as much as 50% at a cost in the order of $10/tonne, according to Munksjo. However, the capital cost may be $20 million, and the generation of substantial amounts of difficult-to-dewater sludge would create a disposal problem. Therefore, this option was rejected by the company. Aspa also tried a polymer (Nalco Chemical No. 7871) and reported no effect at all.

Iggesund, Sweden

Iggesunds Bruk is situated at the Iggesunds fiord north of Stockholm. In 1989 they produced 272,800 tonnes of bleached pulp (softwood and hardwood) and 234,200 tonnes of paper. The market bleached kraft is all softwood. They are equipped with continuous cooking but no oxygen delignification. All pulp is bleached to 88% ISO in the sequence ($C_{80}D_{20}$) E(P) D E(P) D. The Kappa number of softwood prior to bleaching is 31 and 19 for hardwood. All effluent is treated in an aerated stabilization basin except for 20% of the bleach effluent which is discharged directly to the sea. Until 1988 they discharged 4.3 kg/ADt, then increased the amount of chlorine dioxide in the first stage by 5% and the AOX in the effluent was reduced to to 3.2 kg/ADt. Because of more stringent regulations, they had to build a new bleach plant which will start up this year. Thereafter, softwood kraft will be cooked in an MCC system, hardwood in a slightly changed existing digester, all pulp will be oxygen delignified, and all effluent will be biologically treated. Table C.6 summarizes the 1989 data for Iggesund Bruk.

Table C.6 Iggesund Bruk, Effluent data, 1989

	Tonne/year	Tonne/day	Kg/tonne
Production			
Bleached kraft	272,400		
Process water (m^3/day)		130,000	160
COD	19,000	55	71
BOD_7	2,000	5.6	7.3
TSS	2,100	5.9	7.7
AOX	910	2,500	3.3
Tot-N	160	0.450	0.590
Tot-P	18	0.050	0.066

357 operating days. Source: SNV, 1989.[7]

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[7] *The 1990 data was not available at the time of the report writing. AOX figures in particular are expected to be much lower when the new bleach line comes into operation.*

Korsnäs, Sweden

Korsnäsverket is situated in the eastern part of Gävle north of Stockholm. In 1989, the mill produced 538,700 tonnes of pulp (2/3 of which was bleached), and also 421,900 tonnes of paper. Continuous cooking is used for softwood (Kappa 33) and batch cooking for hardwood (17). The softwood kraft was bleached in the sequence CEHDD and the softwood ($C_{90}+D_{10}$) EHDD, both to 89% ISO. The company was required to reduce the AOX from 5.5 kg/ADt in 1987 to 1.5 kg/ADt after January 1991. MCC technology was installed in 1989 to be used for both softwood and hardwood. A new bleach plant was constructed in 1989 with the sequence O O C_{50}/D_{50} EO D D. According to the president of the company they are now using 100% chlorine dioxide, and all effluents are treated in an ASB. Table C.7 summarizes the 1989 data for Korsnäsverket.

Table C.7 Korsnäsverket, Effluent data, 1989

	Tonne/year	Tonne/day	Kg/tonne
Production			
Total kraft	538,700		
Bleached kraft	299,700		
Unbleached kraft	239,000		
Total paper	421,900		
Process water (m^3/day)		230,000	140
COD	27,000	80	
BOD_7	6,000	18	
TSS	5,700	17	13
AOX	750	2,200	2.5
Tot-N	330	0.980	0.340
Tot-P	28	0.082	0.029

342 operating days. Source: SNV, 1989[8].

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[8] *Data for 1990 not available at the time of writing this report. However the data is anticipated to be significantly lower for the year 1990 because of the new bleach plant.*

Mönsterås, Sweden

Mönsterås Bruk is situated at Kalmersund 50 km north of Kalmar and produces softwood and hardwood bleached kraft market pulp through continuous cooking (940 tonnes per day). Mönsterås was built in 1958, with a major modernization in 1979. During the 80s several modifications of the production line were carried out, especially in the bleach plant. In 1989 the total production amounted to 335,900 tonnes. Originally they produced only softwood pulp but since 1982 they are producing both softwood and hardwood pulp by separate runs. The relationship between the softwood and hardwood pulp depends on the market, and in the recent years bleached softwood kraft tended to be slightly more marketable than the hardwood. All pulp is bleached in the same line (O $(D_{25}/C_{70} + D_5)$ (EOP) D (EP) D) to 89% to 90% ISO. The brown stock softwood pulp has a Kappa number of 28 and oxygen delignification reduces this to Kappa 20. Hardwood brown stock is reduced from 17 to 12.5 during oxygen delignification. Table C.8 summarizes the 1989 data for Mönsterås Bruk.

Table C.8 Mönsterås, Effluent data, 1989

	Tonne/year	Tonne/day	Kg/tonne
Production			
Bleached kraft	335,900		
Process water			
softwood		27,000 (m^3/d)	50
hardwood		27,000 (m^3/d)	50
COD			
softwood	4,800	14	26
hardwood	2,700	7.9	18
BOD_7			
softwood	160	0.48	0.89
hardwood	120	0.35	0.79
TSS [9]			
softwood	91	0.26	0.49
hardwood	75	0.22	0.49
AOX			
softwood	190	570	1.1 [10]
hardwood	100	290	0.66
Tot-N			
softwood	47	0.140	0.260
hardwood	38	0.110	0.260
Tot-P			
softwood	24	0.70	0.130
hardwood	20	0.74	0.130

343 operating days. Source: SNV, 1989.

Mönsterås Bruk have applied for permission to construct another bleached kraft line with a capacity of 450,000 tonnes a year on the same site, which together with a small expansion of the existing line will bring the total production capacity up to 800,000 tonnes per year. At this time the existing line will bring the total production capacity up to 800,000 tonnes per year. At this time the project is known to be delayed until probably 1996 due to soft pulp prices. The company expects to be able to build a new line and make enough process improvement to the existing line to ensure that the overall pollution burden in terms of AOX, COD and chlorate will remain unchanged, i.e. that the production of 800,000 tonnes per year should have the same total pollution burden for these variables as the existing 335,000 tonnes per year. It may be of interest to this project to have a brief look at the technology, retrofit as well as new, that will be applied to achieve this.

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[9] *TSS_{70} is suspended material that will be caught in a 70 um wire filter. It would be substantially higher if determined according to the APHA procedure used in Ontario. Refer to discussion on TSS in Chapter 4.*

[10] *The relationship between softwood /hardwood discharges .*

The present lines are operating with:

Treatment of condensates
Extensive spill control
Oxygen delignification (Kappa = 20 for softwood and 12.5 for hardwood)
3 stage post oxygen washing
Bleach plant with sequential addition of chemicals
    Low multiple chlorination
    Oxygen and H_2O_2,enforced extraction (EOP D EP D)
    High-performance mixer in the D-stages
Aerated stabilization basin treatment.

The company plans to make the following process changes:

Extended delignification (MCC), if a retrofit is possible without buying a new digester
Improved brown stock washing prior to the O-stage
Further modifications in the bleach plant; e.g. higher chlorine dioxide substitution, or even ozone or lignox, if these techniques prove efficient. The possibility of UV-filtration of the E_1-stage was considered, but is presently abandoned.

The new line will be built according to the same principles as the modified existing one, only the new line is expected to be even more environmentally efficient due to the installation of completely new equipment.

The existing aerated stabilization basin is expected to be upgraded to an activated sludge plant. The existing ASB has a COD removal efficiency of 45% and an AOX removal efficiency of 50%. The reason for this particularly good AOX removal is stated to be due to the in-plant modifications. Oxygen delignification lowers the need for chlorine chemicals and consequently the overall chlorination ratio of the AOX goes down. This results in the AOX being easier to treat biologically and more can be removed in the treatment plant.

The overall performance standard for the new mill is predicted to be:

AOX	0.4-0.6	kg/ADt
Chlorate	0.4-0.6	kg/ADt
COD	20-23	kg/ADt
TSS	<0.2	kg/ADt
Tot-N	0.2-0.3	kg/ADt
Tot-P	0.05-0.15	kg/ADt

It should be emphasized that not all of the techniques proposed by Mönsterås are proven technologies today, and the mill is not committed to exactly what they have proposed at this stage of the project.

As part of the material to back-up the application, Mönsterås submitted two reports from the SSVL project Environment 90 (SSVL 1990) in which they participated anonymously. Two samples from Mönsterås were submitted, i.e. before and after biological treatment. At the time of sampling they produced extra high tear strength pulp (T-pulp) using the bleach sequence O $(D_{25}, C_{70} + D_5)$ (EOP) D (EP) D. The chlorine multiple was 0.13 for the effluent sample collected prior to treatment and 0.14 for the post-treatment sample. The characteristics of the pulp are summarized in Table C.9 as obtained by the operating conditions stated in Table C.10. The effluent samples went through probably the most extensive chemical characterization ever done on a pulp mill effluent. A few of the chemical results are summarized in Table C.10.

The chemical characterization also included:

Chlorinated phenolics
Chlorinated acetic acids
Fatty and resin acids
Chlorinated acetones
Chloroform
1,1-dichlorodimethylsulfon
Chlorinated verathroles
PCDD/PCDF's
Other lipophilic pollutants
Stable lipophilic pollutants
Molecular mass distributions
Oxidative degradation and analyses of high molecular mass AOX.

The results show that mainly dichlorinated phenolics are formed (approx 27 g/ADt) with less monochlorinated (approx 7 g/ADt) and trichlorinated (approx 10 g/ADt) and hardly any tetrachlorinated during bleaching. Results also indicate that monochlorinated phenolics are virtually eliminated, dichlorinated phenolics are reduced to one-third, whereas tri- and tetrachlorinated phenolics resist biological degradation in aerobic stabilization basin treatment. The latter types of phenolics are by far the most hazardous fraction. The total reduction of chlorophenolics during ASB treatment was 58%. The types of chlorophenolics are derived from phenols, guaiacols, catechols and vanillins as could be expected from softwood pulping. The total level of chlorinated phenolics (40 to 45 g/ADt) is significantly lower than reported from bleach plants without O-stages (80 to 250 g/ADt).

Table C.9 Mönsterås, Pulp characteristics corresponding to effluent samples

	Pulp sample from "before treatment"	Pulp sample from "after treatment"
Unbleached pulp after washing		
Kappa number	28	28
Viscosity (dm^3/d)	1210	1160
Pitch (%)	0.05	0.05
Oxygen delignified pulp		
Kappa number	21	20
Viscosity (dm^3/d)	1100	1150
Sodium carry-over ($NaSO_4$ kg/ADt)	4-6	5-6
COD carry-over (kg/ADt)	3	5
BOD_7 carry-over (kg/ADt)	2	2
Pitch (%)	0.04	0.04
Bleached pulp		
Kappa number after EOP	3.5	3.5
Brightness after D1 (ISO)	82.1	81.4
Final brightness after TM (ISO)	90.5	90.2
Viscosity (dm^3/d)	980	937
Pitch (%)	0.03	0.03

Source: SSVL 90.

Table C.10 Mönsterås, Bleaching conditions corresponding to effluent sampling

kg/ADt	Pulp sample from "before treatment"	Pulp sample from "after treatment"
O-stage		
NaOH	6	8
Oxygen	99	10
Bleaching (O (D_{25}, $C_{70}+D_5$)(EOP) D(EP)D)		
Pulp (ADt/h)	44.3	39.5
Chlorine in C+D	19	21
Chlorine multiple (act. Cl/ADt,kappa	0.9	1.0
Chlorine dioxide pretreatment	6.9	7.6
Chlorine dioxide in C+D	1.4	1.4
Per cent ClO_2 in (D, C+D)	30	30
Active chlorine multiple	1.3	1.5
Oxygen in EOP	6.1	5.4
Chlorine dioxide in D1	16	15
Chlorine dioxide in D2	6	6
Total chlorine dioxide	30	30
Total sodium hydroxide	26	26
Total hydrogen peroxide	2.0	2.1
Oxidation equivalents (OXE/ADt)	3390	3470

Units in above table are kg/AD tonne pulp, unless noted otherwise.
Source: SSVL 90.

Table C.11 Mönsterås, Effluent before and after ASB treatment

kg/ADt	Before treatment	After treatment
Flow (m^3 /ADt)	50	50
Sodium	18	18
COD	61	28
BOD_7	11	1.2
AOX	2.1	1.3
TOCl	1.6	1.2
OCl < 1000	1.1	0.9
OCl < 1000	0.5	0.3
Chlorate	2.7	0.1
Colour Pt	80	58
pH	7.8	7.2

Source: SSVL 90.

Di- and tetrachlorinated acetic acids (approx 64 g/ADt) are virtually eliminated during biological treatment, but these levels are even significantly lower before biological treatment than previously reported values (300 to 1200 g/ADt).

A major fraction of the toxicity to fish originates from fatty and resin acids. About 14 g/ADt of resins acids (0.2 g/ADt) are dichlorodehydroabietic acid, 8 g/ADt of saturated fatty acids and 1 g/ADt of unsaturated fatty acids are reported in the untreated effluent. Resin acids and unsaturated acids are reduced below 1 g/ADt, whereas saturated fatty acids are reduced only to 5 g/ADt.

7 g/ADt of chloroform was reported in the untreated effluent, but this was eliminated during ASB treatment (<0.1 mg/ADt). 9.5 g/ADt of 1, 1-dichlorodimethylsulfon ($CHCl_2SO_2CH_3$) was found in the untreated effluent, and this was only reduced to 6.5 g/ADt with treatment (30% reduction). Only very low levels of chloroacetones were found in the input stream, but none in the effluent. Chlorinated verathroles were not found in the effluent as could be suspected from the work of Nielson (Folke 1991).

The level of PCDD/PCDF was 0.02 ug/ADt Eadon or 0.04 ug/ADt Nordic equivalents in the untreated effluent. The effect of biological treatment is uncertain. In the first sampling, significantly higher levels were found in the treated effluent, but this was not the case in a repeat sampling. Normally PCDD/PCDF are associated with the sludge, and poor TSS control may lead to unexpected high levels in the effluent. Whether this was the case has not been established.

Extractable organochlorines (EOCl) using hexane and persistent extractable organochlorines (EPOCl) (treatment with sulphuric acid adsorbed to kisel gel) were also analyzed. EOCl was reduced from 8.5 g/ADt to 1.5 g/ADt during treatment whereas EOPCl remained approximately the same at 0.5 g/ADt. Earl and Reeve (1989, 1990) reported laboratory values for EOCl being closely related to the amount of chlorine used in the first bleaching stage. The sequence $D_{50}C_{50}E$ on a Kappa 30 unbleached pulp and a chlorine multiple of 0.14 resulted in EOCl 12 g/ADt being formed (Earl 1989, 1990) .

Round 60 lipophilic pollutants were identified by GC/MS analysis. Most of these are reduced significantly during biological treatment, but higher chlorinated ones tend to be more stable.

Treatment with sulphuric acid eliminated most of the lipophilic compounds except chlorinated phenolics, chlorinated and non-chlorinated p-cymens and trimethyl-2-cyclopentenon.

An atomic analysis of the high-mass fraction of AOX gave the following elementary composition:

Untreated: $C_{27.7}H_{31.8}N_{0.1}O_{17.5}S_{0.4}Cl_{1.0}Na_{0.4}Ca_{1.2}$
Treated: $C_{29.7}H_{38.1}N_{0.3}O_{19.2}S_{0.8}Cl_{1.0}Na_{0.9}Ca_{1.4}$

Apart from insignificant hydrolysis, biological treatment does not seem to affect the elementary composition of this high-mass material. An oxidative degradation and subsequent analysis of aromatic carboxylic acids revealed the same kind of aromatics as are the precursors for the chlorophenolics. There were insignificant differences in the findings between the treated and untreated effluent. Molecular masses show maxima in the range from 1,500 to 15,000 for both treated and untreated effluents. The chlorination ratio of aromatic structures is somewhat lower for this high-mass material than for low-mass compounds.

The treated and untreated effluents were subsequently characterized ecotoxicologically by the Swedish Environmental Protection Board Laboratory in collaboration with the Universities of Gothenburg and Uppsala:

Microtox (100% effluent)
5 to 9 weeks physiological test on rainbow trout (100, 500, 2500 times dilution).

Microtox test resulted in $EC_{50/5\ min}$ = 22.9% for untreated effluent and >100% for treated effluent. The conclusions from tests on rainbow trout were reported to be somewhat uncertain. The overall picture shows weak effects only in the highest concentration (100 times) on growth (also after 500 times dilution), the number of red blood cells, (detoxification) enzymes in liver and kidney, muscle glycogen and blood lactate. However, it is reported that biological treatment diminish the strength of the effects.

The Environmental Research Group (MFG) has conducted an extensive assessment of the impact of the present production in the receiving waters (MFG 1990). Control programs for the receiving waters have been carried out since the plant came into operation in 1958. Shortly after the new plant came into operation in 1979 damages were reported in the vicinity of the outfall, and when increased chlorine dioxide substitution was used in 1982 the bladder wrack was killed in a 12 km^2 area. This seriously affected the whole ecosystem in an even larger area. Testing done by MFG in model ecosystems from 1983 to 85 revealed that chlorate was the substance that caused this effect (MFG 1988). Until 1985 the chlorate was discharged at a rate of 3 tonne/day. Today the amounts are less than 0.1 tonne/day due to changes in the first bleaching stage (25% of the ClO_2 are charged in a prechlorination tower) and the operation of the aerated stabilization lagoon with an anoxic zone. However, this situation complicated the impact assessment of today's production as the receiving waters had not yet recovered completely. Advanced ecotoxicological techniques had to be used to eliminate the historical damage from the potential impact of today's operation, including transplant experiments of fish and bladder wrack. The main conclusion reported was that today's operation does not affect the structure and functioning of the ecosystems in the receiving waters. In particular, the growth rate of bladder wrack in the vicinity of the outfall is the same as in areas distant from outfall.

Hylta, Sweden

Hylta Bruk is situated inland in southern Sweden and produces 750,000 tonnes/year newsprint from:

Groundwood
TMP
Magnesium-base sulphite pulp (52% yield)
Deinked secondary fibres.

A new 220,000 tonnes per year paper machine came into operation in 1989. They have a tight water balance in the mill and all wastewater is treated in a rather complex plant including activated sludge, anaerobic treatment and some tertiary treatment.

A breakdown of the water use at Hylta done by Stig Karlsson shows that the secondary fibres and the deink operation are the largest water consumers, 4 m³/tonne, whereas the TMP operation probably contributes less than 1 m³/tonne. The rest is from groundwood and sulphite operations.

Condensates, return sludge and bark presses effluents are pretreated anaerobically. Other effluents go through primary clarifiers before all effluents are blended in the AST aeration tank. The effluent leaving the secondary clarifier is sent to tertiary clarifiers for treatment with flocculants. Table C.12 summarizes the 1990 data for Hylta Bruk.

Table C.12 Hylta Bruk, Effluent data, 1990

	Tonne/year	Tonne/day	Kg/tonne
Production			
Total pulp	644,423		
TMP	192,031		
GW	117,079		
Sec. fibres	223,742		
Mg-sulphite	88,042		
Process water (m³/day)		22,460	12 m³/tonne
COD	4,200	11.7	6.6
BOD_7	620	1.71	0.97
TSS	439	1.2	0.68
AOX [11]	1.4	4.0	0.0024
Tot-N	29	81 kg/day	0.045
Tot-P	6.6	17 kg/day	0.013

352 operating days. Source: SNV, 1990.

The anaerobic treatment system experiences problems when pH adjustments are made in the secondary fibre line with sulphuric acid.

The installation of the anaerobic stage has not effected the quality of the effluent discharged. There were no data available to the authors, but experience elsewhere indicates that there was probably some reduction in operating costs.

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[11] *AOX data is from SNV year 1989 with a total pulp production of 558,500 tonnes/year.*

The sludge and bark of the whole operation is incinerated. Largely due to the addition of coagulants in the tertiary clarifier, only 75% of the waste is actually destroyed, the remaining 25% being discharged as boiler ash. This demonstrates a serious disadvantage of chemically assisted coagulation as a tertiary treatment process, which must be considered in evaluating the benefits attained. Tertiary treatment reduces COD by 15% to 30% but the main reason for installing the system was to control TSS and Total Phosphorus.

Grenaa, Denmark

Denmark has several non-integrated paper mills, most of them owned by Stora, and some of them with excellent environmental performances. Of special interest is Grenaa Papfabrik AS, owned by Danisco.

This mill produces paper and board (e.g. corrugating medium, and various liner boards) for the packing industry from recycled paper. They have two pulping lines and three paper machines, two of which are modern relatively high speed machines. The annual production is presently 160,000 tonnes/year. From 1993 they expect to increase this production to 220,000 tonnes/year by increasing the speed of one of the two modern machines from approx. 450 m/min to more than 800 m/min.

Since the beginning of the seventies they have been committed to water saving programmes, and **since 1989 they have had zero effluent except for rainwater runoff from roofs** etc.

Zero effluent has been achieved in several steps. In 1976 they began to recycle white water from the Fourdrinier wire, reducing the water consumption from 50 m³/tonne to 35 m³/tonne. In 1978 they started to use cooling water for sealing purposes, and in 1983 they went to mechanical sealings, reducing the water consumption to 15 m³/tonne. Installation of flotation clarifiers and several intermediate water storage tanks were the final means of reaching zero effluent. Figure C.26 illustrates the evolution to zero effluent and Table C.13 gives the overall flow balance to produce 100 tonnes of product.

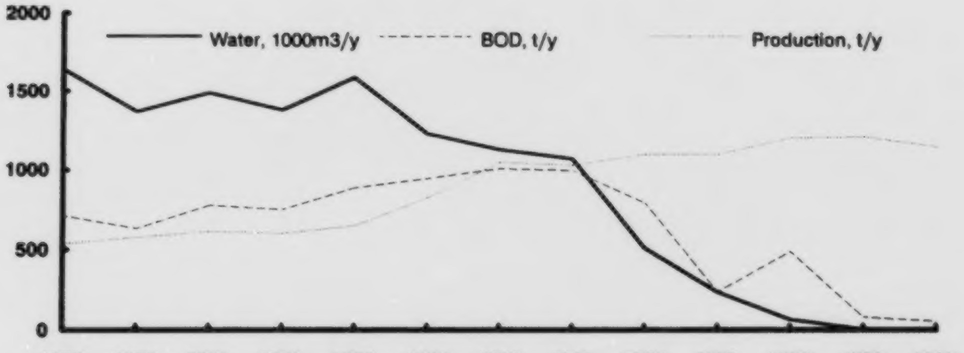

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Figure C.26 Grenaa Papfabrik AS, Denmark, Evolution toward zero effluent

Table C.13 Grenaa Papfabrik AS, Denmark, Mass balance closed cycle mill

Input		Output	
Oil	14.0 tonnes	$CO_2 + H_2O$ + smoke	
Electricity	47335 KW	Steam	134.0 tonnes
Drinking water	61.5 tonnes	Product	100.0 tonnes
Recycled fibre	112.3 tonnes	Cooling water	159.8 tonnes
River water	230.8 tonnes	Solid waste	15.0 tonnes
Chemicals	4.2 tonnes		
Total mass	408.8	Total mass	408.8 tonnes

Quantities shown for production of 100 tonnes of product

The main problem of operating with zero effluent is the microbial growth on starch that leads to formation of organic acids and thus corrosion and potential health problems. Both problems were solved by a combination of stainless steel substitution and the use of biocides (presently nitro-bromo-propandiol).

The mill staff were unable to provide an estimate of the capital cost for the conversion to zero-effluent operation, but are convinced that it was less expensive than the capital charge of 35 million DKK ($7 million) that they would have had to pay for biological treatment at the municipal treatment plant.

Today the mill management is convinced that they took the right decision in adopting the zero effluent approach.

Corbehem, France

La Société Feldmuele Béghin operates a 1500 tonne per day coated paper and board mill at Corbehem, about 150 kilometers NNE of Paris. 500 to 700 tonnes of thermomechanical pulp are produced on site, and the balance of the furnish is purchased pulp.

A new paper machine and expanded TMP production systems were installed during 1990. An anaerobic treatment system was installed as part of this expansion to pre-treat the highest concentration effluent streams. It was in the process of start-up at the time of the author's visit, and was operating well below design BOD removal efficiency during the period (November 1990 to February 1991) that Figures C.27, C.28 and C.29 are based upon. The actual loads on the AST system during this period were about 50% above the nominal loads mentioned below.

The mill white water systems were repeatedly upgraded from 1974 to 1986. Disc and flotation savealls are used extensively.

The effluent treatment system uses a conventional activated sludge process, with two primary clarifiers, two aeration basins and three secondary clarifiers. Influent to the AST system is expected to be 24,500 m^3/day, 8 tonne/day BOD and 24.5 tonne/day COD, but was substantially higher at the time of the author's visit.

The mill is located on the River Scarpe, which is small, slow moving and the recipient of many domestic, agricultural and industrial discharges, so the authorized discharges are exceptionally low by Canadian standards. They are expressed in terms of daily loads, but can effectively be summarized in more general terms as follows :

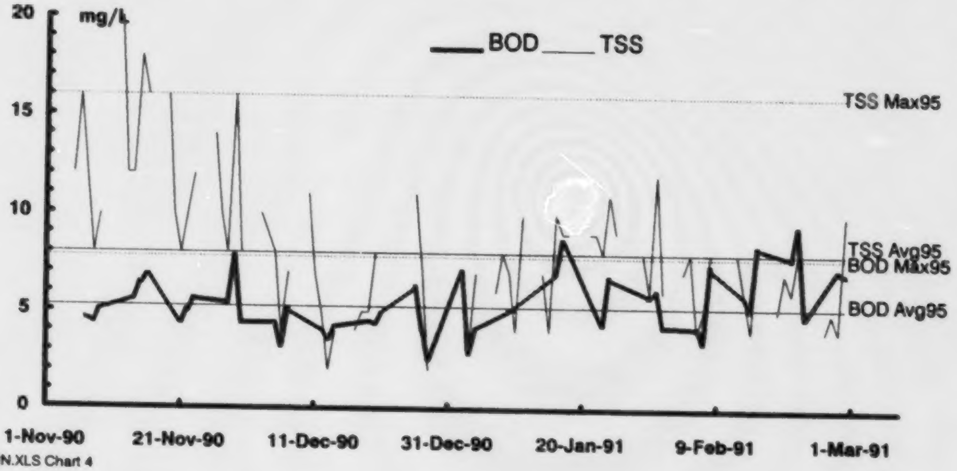
BOD	0.43 kg/t product (Soluble BOD. Equivalent to about 0.6 kg/t by APHA)
TSS	0.7 kg/tonne product
COD	4 kg/tonne product
Effluent flow	30 m^3/tonne product.

The mill complies consistently with these effluent limitations.

The above data refer to maximum instantaneous values. Maximum authorized daily discharges are a few percent lower, while the maximum monthly values are about 10% lower. The limitations expressed in terms of "maximum instantaneous", shown above, are the most stringent. They would be determined by a grab sample, which may not, of course, be taken at the time of the maximum discharge. The effluent characteristics are determined and recorded daily, generally according to North American practice, whereas grab samples are rare. The principal conclusion relevant to this report is that this mill demonstrates the technical feasibility of operating an AST consistently with very low discharges, as shown in Figure C.29.

The plant superintendent advised that the principal difficulty is in complying with the COD regulation, and that they normally have a comfortable margin of safety for the other values (refer to Figures C.27 and C.28).

If the AST plant is operated with equal hydraulic loading on the parallel systems, the primary clarifier upflow rate would be 0.9 m/hour, and the secondary clarifier upflow rate approximately 0.5 m/hr, both somewhat conservative by North American standards. In practice, the loads are unequal, due to design deficiencies, so the upflow rates are rather higher than the design values.



BEGHIN.XLS Chart 4

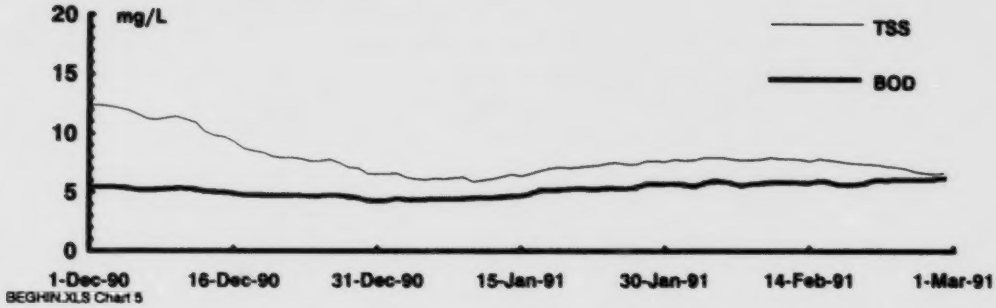
BOD shown is total, calculated from the soluble BOD that was measured
All individual daily values available are plotted.

Figure C.27 Feldmuele, Corbehem, Daily BOD and TSS discharges, winter 90/91

BOD is normally determined three times per week, and the operating data for winter 1990/91 is summarized in Figures C.27 and C.28. The Long Term Average BOD and TSS discharge concentrations were 5.4 mg/L and 8.3 mg/L respectively, which are very close to the Avg_{95} values shown on Figure C.27. Due to the start-up of the number 5 paper machine and the anaerobic treatment system the influent load to the AST was variable, but was generally above design.

In the past the TMP mill was operated as a CTMP mill, and the plant superintendent commented that the treated effluent BOD was normally almost 100% higher when the sulphur from the CTMP operation was in the raw effluent. The anaerobic treatment system was designed on the assumption that sulphur compounds would not be used for pulping in the future.

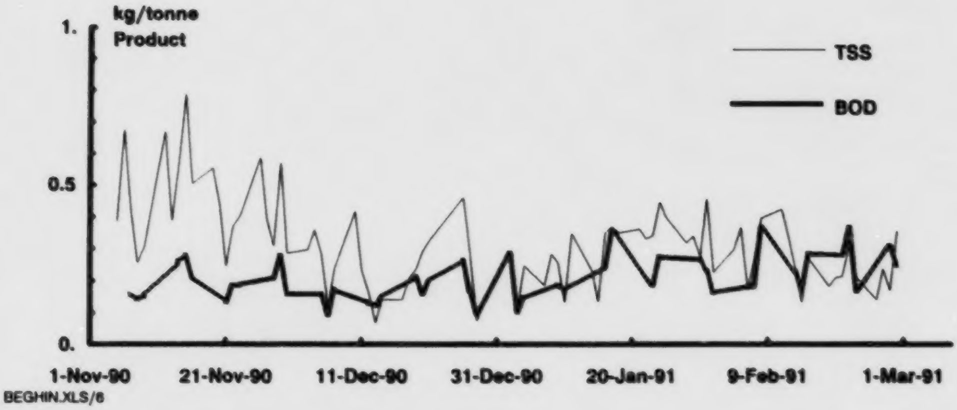
In view of the start-up status of the anaerobic system, it was not considered useful to attempt to analyze its operation.



BOD shown is total, calculated from the soluble BOD that was measured winter 90/91

Figure C.28 Feldmuele, Corbehem, Rolling 30 day average BOD and TSS discharges

The average production based BOD and TSS discharges for the period for which data were available, November 1990 to March 1991, were 0.2 kg/t and 0.3 kg/t respectively. Figure C.29 presents the daily production based loadings, for all days on which analyses were performed for the period shown.



Total BOD shown, calculated by authors from TSS and measured soluble BOD

Figure C.29 Feldmuele, Corbehem, Production based BOD and TSS daily loadings

Feldmuehle Langerbrugge NV

Company	Feldmuehle Langebrugge NV
Location	B-9000, Gent, Belgium
Personnel	Luc de Walque, Project Engineer for installations Luc de Smet, Responsible for operations PHONE: 32 - 91 53 87 31 FAX: 91 53 93 41
Products	Newsprint and magazine grades, 900 tonne/day Newsprint is TMP + Deink stock, 300 tonne/day

Pulping	TMP	125 tonne/day
	Flotation Deinking	180 tonne/day
	Groundwood	300 tonne/day

Purchased kraft 15 to 20% of magazine grades
Clay filler about 20%

Regulatory requirements

Regulatory requirements consist essentially of the maximum allowable concentrations indicated in Table C.14 The mill measures TSS and COD daily, and BOD less often, but does not report to authorities. The regulatory authority runs 3 to 4 checks per year, lasting one week each. Effectively COD is the most significant limit. The mill is permitted to deduct measured incoming pollutants from discharges when calculating loadings.

The effluent can normally comply with the regulations without any serious difficulty, so it is not necessary to operate the plant for maximum efficiency, allowing costs of nutrients, chemicals and power to be optimized. However, the recently introduced effluent taxes may change the optimum operating point.

Raw effluent loads

Flow	27,600 m^3/day
BOD	9600 to 11,000 kg/day
TSS	27,000 kg/day
Temperature	30 to 40 deg C

Table C.14 Feldmuehle, Langerbrugge, Raw water and effluent characteristics

	Incoming Water	Untreated Effluent	Actual Effluent	Regulatory Requirement
TSS	25	1000	5 to 60 (mostly 15 to 20)	60
BOD	25 to 30	350 to 400	10 to 15 (rarely measured)	50
COD	100		150 to 200	180
Total P			<1	1
NH_3 N			<2	2

Treated effluent TSS determined every 2 hours, inspection of several days records indicated >90% of data in range 15 to 20. COD measured daily, but BOD relatively rarely.
Data expressed in mg/L.

Effluent taxes

A system of effluent taxes was recently introduced. The tax is calculated separately for three classes of pollutants, organics, metals and nutrients.

The organic "pollution units" are calculated as:

$$0.2*Q/180*(.35\ TSS/500+0.45(2\ BOD+COD/1.35))$$

The metal "pollution units" are calculated as

$$Q*(10(Cd + Hg) + (\text{Other heavy metals}))$$

The nutrient "pollution units" are calculated as

$$Q*(N + P)/10$$

where Q is flow in m^3/day, and the pollutants are expressed in mg/L.

The mill can deduct incoming pollutants in each class from the outgoing, but cannot take credit across classes. The proposed tax rate is 600 FB/unit/year, based on annual average discharges, but the rate is under negotiation. ($1Cdn was approximately 0.03453 FB whne this mill visit report was written in April 1991, so the tax would be approximately $21/unit/year.)

Treatment System

Overview

The effluent treatment system consists of two similar lines operating in parallel. Each includes a conventional primary clarifier and a two stage activated sludge system. All sludge is collected in a gravity thickener, where its consistency is raised to about 10%, then dewatered by Andritz twin wire presses. The following description refers to one line.

Primary treatment

Conventional mechanically cleaned bar screen, followed by 24 m diameter primary clarifier, with upflow rate of 0.75 m/h[12]. BOD reduction about 10% in the primary stage. The inlet TSS concentration is relatively high. There are no chemicals used.

Stage 1 activated sludge

The first stage aeration tanks have a total volume of 3240 m^3 and 288 kW installed aeration power. The first of 6 aerators in each basin is not run, and the entry section is used as a selector, to inhibit the growth of filamentous bacteria. Hydraulic retention time is approximately 2.8 hours, including the selector. All aerators are low speed surface type, with two speed motors, which are used to control outlet dissolved oxygen to 0.5 to 1 mg/l.

Nutrients are controlled to 100:3:0.5 BOD:N:P ratio. A substantial proportion of the nutrients required are in the raw effluent, so that the amounts added are quite low, and sometimes zero. The mill has not seen any advantage in adding greater amounts, although they have extensive experience in operating with significantly higher quantities of nitrogen input in the form of a waste stream from an adjacent chemical plant (currently shut down).

The single secondary clarifier for each line of stage 1, are suction type (one rectangular and one circular), total surface area 900 m^2, equivalent to an upflow rate of 1.3 m/hour. Sludge is returned to primary clarifier in one line, and to the inlet of the aeration basin in the other. The operators do not see any clear difference in performance for either technique.

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[12] *Upflow rates, hydraulic detention times etc calculated by N McCubbin from plant volumes, assuming 1150 m^3/hr flow.*

Stage 2 activated sludge

The second stage is similar to the first, but the aeration tanks have 4 hours retention and are operated with dissolved oxygen levels of 1.5 to 2.5 mg/L. The hydraulic loading of the secondary clarifier is 0.7 m/hour.

Sludge dewatering

All sludge is thickened in a gravity thickener to a reported consistency of 10% (at the time of the visit it appeared to be in this range, but no data were available)

Effluent quality

As indicated in Table C.14 above, the effluent quantity is good, but not exceptional. This plant was visited because of verbal reports of exceptionally good operating performance with two stage AST systems in general, and this one in particular. While this may be possible, it has not been demonstrated. In any event, there were not sufficient data available to consider this a BAT plant for the purposes of this study.

Appendix D

Notes on Regulatory Issues

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Introduction

The literature was scanned for the purpose of identifying countries with tight regulations. Normally, the regulations of a country reflect the performance of the industry - at least among the OECD countries. Therefore the regulation standards reflect what is technically and economically achievable for the pulp and paper industry of that country. On this basis, the authors have found it worthwhile to include some notes on four countries, assuming that the Ministry is already familiar with Canadian regulations. These countries are: Finland, Germany, Sweden and USA.

Recent discussions on regulatory issues were conducted recently for the Commission of the European Communities (EEC 1989; Folke 1989, 1990). Jaakko Pöyry conducted a study for Procter and Gamble in 1990, also on regulatory issues in Western Europe and North America (Sjöblom 1990) and for the Nordic Council of Minsters (NCM 1989).

USA

The US pulp and paper industry comprises some six hundred mills; of these one hundred and four manufacture bleached chemical pulp, mostly kraft although a few sulphite mills are still in operation.

Present USEPA Regulations

EPA regulations established different kinds of technology-based effluent limitations and standards through the late 1970s and early 1980s. The principal stage for most mills was publication of the 1982 development document (EPA 1982). All regulations are technology-based and are based on treatment technologies capable of reducing pollutant levels. They are not developed with any consideration for the specific receiving waters. The regulations include (Hanmer 1988):

Best Practicable control Technology currently available (BPT):

> Based on the average of the best existing performance of direct discharges in the industry. BPT is generally the first stage or baseline regulation for an industry. To meet BPT only external treatment was required.

Best Available Technology economically achievable (BAT):

> Represents the best existing performance in the industry, controlling the direct discharge of toxic and non-conventional pollutants. BAT is the second stage of regulation for these pollutants. BAT requires major internal mill improvements, biological waste treatment, and physical-chemical treatment. In addition to BOD and TSS it includes pH, zinc and colour. Toxic substance effluent limitations would also be set in BAT. [1]

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[1] *Note that the EPA definition of BAT differs from the Ontario Definiton.*

Best Conventional control Technology (BCT):

Controls the direct discharge of conventional pollutants in the second stage of regulation.

New Source Performance Standards (NSPS):

Based on best available demonstrated technology and applies to new direct discharging facilities. "All" pollutants are controlled.

Pretreatment Standards control for Existing (PSES) and New Sources (PSNS):

Pollutant discharges that pass through, interfere, or are incompatible with the operation of publicly owned treatment works.

Table D.1 presents current USEPA BPT and NSPS standards for BOD_5 and TSS. pH has to be within 6 to 9, in all cases. NSPS standards for conventional pollutant control were established based on the same technology as BPT plus additional flow reducing in-plant process controls. BAT, PSES and PSNS are generally concerned only with the discharge of trichlorophenol, pentachlorophenol and zinc (compounds present on the list of 129 priority pollutants). Pentachlorophenol originates from its use as a slimicide, and trichlorophenol may orginate from slimicide use or chlorine bleach plants. EPA assumes it to be possible to find substitute slimicides for pentachlorophenol, at no additional cost. Since 1986, BCT was specified as being the same as BPT in terms of these conventional pollutants.

An effluent limitation is an upper limit of the amount of pollutant discharge allowed per day or average of 30 consecutive days. The limitations are derived by calculating the product of a variability factor and a long-term average discharge load. Two types of variability factors are used and include a daily maximum factor and a 30-day maximum factor. The daily maximum factor is the ratio of (1) a value that would rarely be exceeded by the daily pollutant discharge to (2) the long-term average daily discharge. The daily limitation is the product of the variability factor and the long-term average. The 30-day limitation is the product of the 30-day variability factor and the long-term average. The maximum daily variability factor is the ratio of the 99th percentile of daily pollutant discharge factors to the estimated long-term average daily pollutant discharge. One daily and one 30-day average variability factor subsequently have to be determined for BOD_5 and TSS.

BAT, NSPS, PSES and PSNS standards are generally based on adjusted concentrations (limit concentration x BPT unit flow/actual mill unit flow), or as an alternative on a mass basis (kg/ADt). Table D.1 presents the range of limit concentrations and mass limits used by EPA.

Table D.1 Current BPT and NSPS standards for BOD and TSS in USA (kg/ADt)

	Maximum 30-Day Average				Maximum per Day			
	BOD		TSS		BOD		TSS	
	BPT	NSPS	BPT	NSPS	BPT	NSPS	BPT	NSPS
Bleached kraft: dissolving pulp	12.25	8.4	20.05	14.3	23.6	15.6	37.3	27.3
Bleached kraft: market pulp	8.05	5.5	16.4	9.5	15.45	10.3	30.4	18.2
Bleached kraft: paperboard, coarse and tissue	7.1	4.6	12.9	7.6	13.65	8.5	24.0	14.6
Bleached kraft: fine papers	5.5	3.1	11.9	4.8	10.6	5.7	22.15	9.1
Dissolving sulphite pulp								
Nitration grade pulp	21.5	14.5	38.05	21.3	41.1	26.9	70.65	40.8
Viscose grade pulp	23.0	15.5	38.05	21.3	44.3	28.7	70.65	40.8
Cellophane grade pulp	24.95	16.8	38.05	21.3	48.05	31.2	70.65	40.8
Acetate grade pulp	26.4	21.4	38.05	21.5	50.80	39.6	70.65	41.1
Sulphite: paper (blow pit wash)	2.36*X[1]		3.03*X		4.38*X		5.81*X	
Bisulphite/surface condensers	16.55		23.65		31.8		43.95	
Bisulphite/barometric cond.	18.05		28.1		34.7		52.2	
Acid sulphite/surface cond.	16.8		23.65		32.3		43.95	
Acid sulphite/barometric cond.	18.5		28.1		35.55		52.2	
Sulphite: paper (drum wash)	2.36*X[1]		3.03*X		4.38*X		5.81*X	
Bisulphite/surface condensers	13.9		23.65		26.7		43.95	
Bisulphite/barometric cond.	15.3		28.1		29.4		52.2	
Acid sulphite/surface cond.	15.5		23.65		29.75		43.95	
Acid sulphite/barometric cond.	16.9		28.1		32.5		52.2	
Continuous digesters	19.85		28.95		38.15		53.75	
Soda	7.1		13.2		13.7	5.7	24.5	9.1
Unbleached kraft	2.8		6.0		5.6		12.0	
Linerboard		1.8		3.0		3.4		5.8
Bag paper a.o. mixed products		2.7		4.8		5.0		9.1
NSSC-Ammonia	4.0	1.6	5.0	3.0	8.0	3.0	10.0	5.8
NSSC-Sodium	4.35	1.6	5.5	3.0	8.7	3.0	11.0	5.8
Unbleached kraft-NSSC	4.0	2.1	6.25	3.8	8.0	3.9	12.5	7.3
Groundwood: chemimechanical pulp	7.05		10.65		13.5		19.75	
Groundwood: thermomechanical pulp	5.55	2.5	8.35	4.6	10.6	4.6	15.55	8.7
Groundwood: fine papers	3.6	1.9	6.3	3.0	6.85	3.5	11.75	5.8
Groundwood: course papers, molded products & news	3.9	2.5	6.85	3.8	7.45	4.6	12.75	7.3
Non-integrated paperboard	3.6	1.9	2.8	1.5	6.5	4.0	5.8	3.5
Non-integrated fine paper								
Wood fibre	4.25	1.9	5.9	2.3	8.2	3.5	11.0	4.4
Cotton fibre	9.1	4.2	13.1	4.9	17.4	7.8	24.3	9.5
Non-integrated light paper	13.2	6.7	10.6	5.2	24.1	13.7	21.6	12.0
Electrical grade papers	20.9	11.7	16.7	9.2	38.0	24.1	34.2	21.1
Non-integrated tissue	6.25	3.4	5.0	2.6	11.4	7.0	10.25	6.0
Non-integrated filter and non-woven papers	16.3	8.3	13.0	6.6	29.6	17.1	26.6	15.0
Deinking	9.4		12.95		18.1		24.05	
Fine paper		3.1		4.6		5.7		8.7
Tissue paper		5.2		6.8		9.6		13.1
Newsprint		3.2		6.3		6.0		12.0
Waste paper								
Non-integrated tissue from	7.1	2.5	9.2	5.3	13.7	4.6	17.05	10.2
Paperboard								
Noncorrugating medium furnish	1.5	1.4	2.5	1.8	3.0	2.6	5.0	3.5
Corrugating medium furnish	2.8	2.1	4.6	2.3	5.7	3.9	9.2	4.4
Molded products	2.3	1.1	5.8	2.3	4.4	2.1	10.8	4.4

[1] X = $10^{0.017x}$, where x = % sulphite pulp in final product.

Source: USEPA, various documents.

Table D.2 USEPA discharge limits for Pentachlorophenol, Trichlorophenol and Zinc

		ug/L	g/ADt
Pentachlorophenol			
BAT	unbleached	11-29	0.58-9.3
	bleached	11	1.4-3.3
NSPS	unbleached	12-155*	0.58-9.3
	bleached	12-14*	1.4-3.3
PSES	unbleached	11-32	0.58-8.0
	bleached	11	1.4-3.3
PSNS	unbleached	12-171	0.58-8.0
	bleached	12-14	1.4-3.3
Trichlorophenol			
BAT	unbleached	10-68	0.3-6.9
	bleached	68	8.8-21
NSPS	unbleached	11-104*	0.3-6.9
	bleached	74-84*	8.8-21
PSES	unbleached	10-82	0.30-8.4
	bleached	82	11-25
PSNS	unbleached	11-126	0.3-8.4
	bleached	89-101	11-25
Zinc (bleached groundwood)			
BAT		3000	260-300
NSPS		3000	170-210
PSES		3000	260-300
PSNS		3000	170-210

*Non-continuous discharges
Source: USEPA

USEPA considers "their current effluent limitations guidelines to be outdated for many segments of the industry" (Heath 1991). As explained in the paper, the present standards were developed in the late seventies based on an extensive monitoring program, and reflect the environmental standards of US mills at that time. Virtually all US pulp and paper mills comply with these standards today. In the last couple of years, USEPA has been dealing with the PCDD/PCDF problem as well, and many US mills have modified or are about to modify their bleach plants to minimize the amount of PCDDs/PCDFs being discharged. Also, the USEPA has paid attention to the extensive ecotoxicological programs that have been conducted in Scandinavia, showing the chronic toxicity effects of many pulp mill operations on the receiving waters, including those that do not produce bleached pulp. So, they have initiated a data collection program that should be finished by the end of this year. A proposal for new regulation is expected in 1993 and the new standards are expected to be promulgated in 1995 (Heath 1991).

The new regulations will basically be based on the same philosophy, having a set of BPT/BCT standards that apply to wastewater treatment plants only. The BAT/NSPS/PSES/PSNS standards will most likely be valid for bleach plant operations only, since these are known to be a source for many toxic pollutant discharges. Data for more than 200 chemicals will be collected, and limitations may be developed for several organic pollutants of concern.

Finland

Regulations

Finland has set the goal that all bleached pulp plant operations should, by 1995, be limited to:

1.4 kg/ADt AOX for mixed, bleached hardwood and softwood kraft
2.0 kg/ADt AOX for bleached softwood kraft
1.0 kg/ADt AOX for bleached hardwood kraft
65 kg COD for bleached kraft
0.06 kg phosphorus for bleached kraft

The specific loads as of 1987 and as expected by 1992 are presented in Table D.3.

Table D.3 The specific loads in 1987 and as expected by 1992

	Process water		BOD$_5$		COD		P	
kg(m^3)/tonne	1987	1992	1987	1992	1987	1992	1987	1992
Bleached kraft	98.7	79.4	16.4	8.2	90.2	58.7	0.109	0.086
Sulphite pulp	200	80	35	9.0	180	90	0.200	0.80
Paper	43.1	26.6	3.4	2.1	11.1	7	0.013	0.013
Board	40.2	27.4	6.0	3.4	18.5	11.9	0.016	0.015
Liner	24.0	16.0	7.0	4.0	24.0	16.0	0.007	0.010

Source: Communication from the Finnish National water Board.

The bleached hardwood kraft operation amounted to 1.7 million tonnes in 1987 and is expected to be up to 2.0 million tonnes in 1992. The similar figures for softwood bleached kraft are 2.0 million tonnes and 2.5 million tonnes respectively (Junna 1991). There are 17 bleached pulp mill operations in Finland having an average discharge of AOX 2.7 kg/ADt in 1991. By the end of this year, 25% of these mills will operate with extended cooking (mostly MCC), and 40% will have oxygen delignification. Decreased use of molecular chlorine and increased use of chlorine dioxide is another, although not quantified, trend.

Finnish Industry

Although there are many excellent mills in Finland, none of these use a technique or combination of techniques, that is not found in North America. Therefore, the authors have not discussed any of these in detail. Jaakko Pöyry prepared a report for the Nordic Council of Ministers in 1989 to address the needed reduction of chloro-organic discharge in the Nordic Pulp Industry (NCM, 1989). The report is now a few years old, and some technologies have since been developed further, e.g. chlorine dioxide substitution as well as ozone and enzyme bleaching technologies, but basically the report suggests the well known measures such as extended delignification, oxygen delignification, lower chlorine multiple etc. The authors consider that it is rather conservative in its estimates of what the different techniques can achieve, even considering that it is 2 years old. The report does not address Nordic pulp mills' situations in particular.

Norway

The Norwegian pulp and paper industry is mostly based on mechanical pulp, i.e. very few bleach plants are to be found, and only one bleached kraft mill (Tofte). Over the past years quite a few old sulphite pulp mills have been closed or converted to mechanical pulp mills. Industrial standards for pulp mills in Norway are:

Fibre loss:	0.5 %
AOX (kraft):	2 kg/ADt
AOX (sulphite):	1 kg/ADt.

Norwegian mills normally do not practice very tight water use or extensive wastewater treatment. This may be changing now and in the years to come. However, for the purpose of this study the authors have not looked further into the Norwegian pulp and paper industry.

Sweden

There are 79 pulp and paper mills in Sweden. 25 mills produce kraft pulp, 9 mills produce sulphite pulp, 1 mill with NSSC, 8 mills CTMP, 6 mills TMP, 13 mills GW, 6 mills produce fibre board and 26 mills are non-integrated paper mills. Some of the mills produce more than one type of pulp. Clearly it is outside the scope of this report to go into details on all the mills, so the authors have chosen to address only the mills with excellent environmental standards in one or more of the aspects relevant to the scope of this report.

Sweden has been leading the worldwide push toward chlorine free pulp bleaching. The Swedish Environmental Protection Board has proposed the following regulation of AOX for the future:

Table D.4 Proposed Swedish AOX regulations

	AOX (kg/ADt)	
Year	Softwood	Hardwood
1992	2	1
1995	1	0.5
2000	0.5	0.3
2010	0.1	0.1

Source: Swedish Plan for Protection of the Sea (SNV, 1990)

The following information has partly been taken from (SNV 1989; Kemikalieinspektionen 1989). Additional information was acquired either directly from the mill and/or from the official files of the Swedish Government in Stockholm. In no case, has confidential information been used.

The Table D.5 presents the data from Swedish bleached kraft pulp mills.

Table D.5 Swedish bleach kraft pulp mill discharges in 1989

Mill	Location	Production ADt/y	Water m^3/ADt	AOX kg/ADt	BOD_7 kg/ADt	COD kg/ADt	TSS kg/ADt
Aspa	L. Vättern	97,000	110	2.1	13	46	5.2
Gruvön	L. Värnen	263,000	93	2.0	12	67	3.7
Husum	Baltic	582,000	120	2.0	19	85	26
Iggesund	Baltic	273,000	160	3.3	7.3	71	7.7
Karlsborg	Baltic	248,000	110	2.0	5.7	57	9.5
Korsnäs	Baltic	300,000	140	2.5	(20)	(90)	13
Mönsterås	Baltic	335,000	50	0.86	0.84	22	0.49
Mörrum	Baltic	330,000	88	1.9	16	61	3.3
Norrsundet	Baltic	246,000	63	1.8	12	52	1.7
Östrand	Baltic	312,000	130	2.2	19	70	14
Skärblacka	Lake Glan	154,000	83	1.0	4.8	36	5.4
Skoghall	L. Värnen	96,000	95	5.9	19	66	5.3
Skutskär	Baltic	428,000	110	1.8	19	47	4.4
Vallvik	Baltic	158,000	170	3.5	16	56	4.1
Värö	Kattegat	276,000	130	4.7	26	92	4.9

Mixed hardwood and softwood. Source: (SNV 1989)
TSS normally determined by a wire filter in Sweden. Data would be higher for Ontario analysis, (refer to Chapter 4)

In addition to these kraft mills, Domsjö, Lessebo, Nymölla and Billerud have bleached sulphite operations.

Performance data for Swedish newsprint mills are presented in Table D.6.

Table D.6 Swedish TMP newsprint mills as of 1989

Mill	Location	Production tonne/y	Water m^3/ADt	AOX kg/ADt	BOD_7 kg/ADt	COD kg/ADt	TSS kg/ADt
Braviken	Inland	424,000	31	0.0013	0.46	1.6	0.3
Hallsta[1]	Baltic	503,300	17	0.0040	2.6	10	1.2
Hylte[2]	Inland	572,000	14	0.0024	0.54	5.9	0.6
Kvarnveden[3]	Inland	577,000	22		2.8	8.9	2.3
Ortviken	Baltic	550,000	21	0.0026	4.1	19	4.3

[1] Including 102,000 tonnes groundwood and 82,000 tonnes secondary fibres
[2] Including 112,000 tonnes groundwood and 176,000 tonnes secondary fibres and 93,000 tonnes Mg-sulphite
[3] Including 157,000 tonnes groundwood
Source: (SNV 1989)
TSS normally determined by a wire filter in Sweden. Data would be higher for Ontario analysis, (refer to Chapter 4)

Germany

The annual use of fibres in Germany amounts to 9.6 million tonnes (ADt). 3.7 million tonnes are virgin chemical pulp, 1.5 million tonnes are mechanical pulp, and 4.3 million tonnes are secondary fibres. The chemical sulphite pulp production amounts to 0.6 million tonnes; the rest is imported. There are approximately 200 paper mills, and only ten chemical pulp mills (1987 information from CEPAC statistics). The ten chemical pulp mills have all changed their processes within the last 2 to 3 years.

The chemical sulphite pulp mills are mostly using softwood (spruce), but some hardwood (beech) is supplied to the pulp mills as well. There are no pulp mills that exclusively use hardwood. Batches of hardwood are run when appropriate.

Most of the following is based on personal information (Dr. Christian H. Möbius personal communication, Papiertecyhnische Stiftung, München PTS 1989). Ten pulp mills are producing chemical bisulphite pulp, one semi-chemical pulp (on its way to change the process to produce corrugated board from secondary fibres) and 25 mechanical pulp (ten of which are very small, i.e. less than 25,000 tonne/year). Among the mechanical pulp mills, two are producing TMP and two (or three) pressurized ground wood - the rest are ordinary groundwood pulp mills.

Sulphite pulping in Germany is all magnesium based. However, Thyssen GmbH is constructing a 120,000 tonnes per year organocell pulp mill at the Bayerishe Zellstoff GmbH mill in Kelheim. This mill will be finished in 1992 at the cost of 174,200 DM[2]. The process is sulphur free and the pulp will be bleached molecular chlorine free (possibly chlorine compound free altogether), although this matter is not confirmed at the moment. This method applies highly alkaline conditions with NaOH and MeOH. Refer to Laxén (1988) for a more complete description. The MeOH is expected to be recovered in the process. Another new pulping technology, which may become operative in Germany in the near future, is based on a cooking mixture of formic acid and acetic acid.

The range of products of the German mills includes the following grades (Huber 1988):

Semi-chemical pulp
Bleached paper pulps
Bleached dissolving pulps
High-viscosity dissolving pulps.

Basically no molecular chlorine is used in the German sulphite pulp mill bleaching, and only two or three stages are used, $E_{OP}DD$ or similar. In older mills H was used, but this has been changed to D over the past few years. Generally oxygen delignification is also used. Investigations have shown that organochlorine compounds are not transferred with the pulp to the paper mills to any significant extent (Möbius 1988).

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[2] *Deutche Mark = $0.67 (April 1991)*

Wastewater Treatment

Two-stage or even three-stage biological treatment is frequently used in German pulp and paper mills. The first stage is preferably anaerobic, the second choice is normally trickling filter, or occasionally activated sludge (Möbius 1986). The final stage is always activated sludge.

Papiertechnische Stiftung in Munich has an anaerobic treatment system achieving COD values ranging from 2,000 to 5,000 mg/L - sometimes below 2000 mg/L. Generally, SO_2 has to be stripped prior to anaerobic digestion.

Phosphate removal is an important issue in Germany and research has shown that a combined flocculation and sand filtration may bring the effluent down to 0.1 P mg/L (Dr. Christian H. Möbius personal communication, Papiertecyhnische Stiftung, München PTS 1989).

Emission Standards

New pulp mill effluent discharge standards came into effect in 1989, and are summarized in Table D.7

Table D.7 Proposal for new emission standards for German mills

	TSS	COD	BOD_5		NH_3-N[1]	Tot-P[2]	AOX[3]
	mg/L	kg/t	kg/t	mg/L	mg/L	mg/L	kg/t
Sulphite pulp mills	50	70	5			0.1	1
Mechanical pulp		5		25			
Uncoated fine paper	50	3	1		10	3	0.04
Coated fine paper	50	6	2	-	10	3	0.04
Tissue	50	9	3	-	10	3	0.04
True parchment	50	12	6	-	-	3	0.025
White board	-	2	-	25	10	3	0.02
Integrated groundwood paper	-	3	-	25	10	3	0.01
if more than 50% TMP is used	-	5	-	25	10	3	0.01
Waste paper	-	5	-	25[4]	10	3	0.012

[1] For effluents exceeding 500 m^3/d

[2] For effluents exceeding 1000 m^3/d

[3] In special cases this value may increase to 0.12 and 0.2 kg/ADt

[4] If water use is lower than 10 m^3/t the limit is 0.25 kg/t up to a maximum of 50 mg/L

Prior to treatment the values for mechanical pulp mills are typically 10 kg BOD/t and 25 kg COD/t, i.e. more than 80% COD removal is necessary and so is more than 90 % (95% to 97%) BOD removal

The 0.1 mg/L Phosphorus value is based on a taxation system. Exceeding this value requires taxes to be paid.

A German paper mill produces in the order of 3 to 9 kg COD/tonne paper. 60% have on-site biological treatment, 20% to 25% discharge to municipal sewers, and 15% to 20% have only chemi-mechanical treatment. Treatment of paper mill effluents has been a major research topic at the PTS, as has anaerobic treatment of deinking wastewater (Möbius 1987, 1988, 1988 and 1989).

The new German emission standards for paper mills will affect the requirement for imported kraft pulp especially because AOX carry-over from this type of pulp is the only important source. The standards came into effect in 1991.

Apart from the organocell process, the German pulp mills have little to offer the Ontario pulp and paper industry in terms of technology. The chemical pulp mills are all magnesium based low-yield sulphite with conventional recovery systems. Some of the pulp and paper mills have quite good treatment plant designs. The authors consider that the taxation system that applies to effluent discharges does a lot more for the environment in terms of encouraging excellent operational management than the design itself.

Appendix E

Low-Effluent Newsprint Mill Simulation

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1 Introduction

1.1 Concept and Objectives

Newsprint mills in Eastern Canada, including Ontario, differ from most others in the Western world in that they manufacture chemical pulp on-site to reinforce groundwood pulp, and do not have a chemical recovery system for the spent pulping liquor[1]. This results in the discharge to receiving waters of the chemicals (generally of little environmental significance) and the organic matter removed from the wood. The latter have a high BOD and are generally acutely toxic to fish, as discussed in Chapter 3. Refer to Chapter 4 and Appendix B for detailed data on the effluent from newsprint mills. A typical ratio of chemical to mechanical pulp would be 25%.

Conventional sulphite recovery processes are impractical for both technical and economic reasons. The available technology is not adapted to the high inorganic content of the waste liquors generated by the high-yield pulping processes used in Ontario (typically from 70% to almost 90%). The small scale of the production systems is a major impediment to economic operation of any recovery system.

As is apparent from the estimated costs for secondary treatment for the Ontario newsprint mills, it is expensive to treat the BOD from the sulphite mills biologically.

Mills outside Eastern Canada have generally abandoned the high-yield sulphite + groundwood pulp furnish for newsprint in favour of either :

100% TMP
Groundwood + kraft reinforcing pulp
A combination of the above

The kraft pulp is usually produced on-site, since few mills can survive economically with purchased kraft. Some Quebec mills have adopted the 100% TMP approach over the past ten years, as indicated below, while Western Canadian and US mills often use kraft pulp. It is not uncommon for the two approaches to be combined, since it is not unreasonable to use, say 98% TMP with 2% purchased kraft.

This appendix examines the possibility of replacing the pulp mills in a traditional Ontario newsprint mill with a modern TMP mill, equipped with the type of effluent concentration and recycle system envisaged at two Western Canadian market CTMP mills. The essential difference would be that the pulp would be washed to recover 90% or more of the organics and acutely lethal materials before being passed on to the paper mill. The effluent from the latter would then be low in BOD and non-lethal.

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[1] *Spruce Falls Power and Paper at Kapuskasing is an exception.*

1.2 Current installations

In the past two years, the companies listed in Table E.1 have proposed zero-effluent mills, and have made application to the relevant provincial regulatory authorities for permission to build them The first two are market bleached CTMP mills, and the third is based on the pressurised groundwood process.

Table E.1 Proposed effluent-free mills in Canada

Company	Town	Province	Mill capacity MTPD	Projected start-up date
Louisiana Pacific	Chetwynd	BC	500	July 1991
Miller Western	Meadow Lake	Sask	600	1992
Orenda	Stewart	BC	300	1992 ?

The Chetwynd and Meadow Lake installations are described in some detail by Barbe (1990)

The current proposals for effluent-free mechanical pulp mills are based on the foregoing concepts, and include some washing of the pulp. The recently introduced alkaline peroxide variation of CTMP is used, and it has the advantage of being sulphur free, which simplifies incineration of the concentrated waste.

The proposed pressurized groundwood mill at Stewart, BC, will have an advantage over the other effluent-free mechanical pulp mills because it will not use any pulping chemicals, so the effluent to be evaporated would be sodium free too. However, it is likely that some brightening chemicals will be required, reducing this advantage. Note that although hydrogen peroxide bleach itself is free of inorganic metals or salts, it is necessary to use alkali with it.

The equipment necessary for the above mentioned three mills is proven in industrial service although not necessarily in the pulp and paper industry. There are several competitive, established suppliers with extensive track records for all items. The process design is new.

The authors have examined the engineering basis for these concepts, and consider that they are sound. There is no doubt that there will be unforeseen difficulties with the closed cycle processes, probably including deposit formation, maintaining white water inventories while parts of the mills are down for repair, preventing excess water from entering the process, and developing suitable operating strategies. Full scale experience will be required to demonstrate whether these problems can be solved or not.

The modern mechanical pulping processes that the currently proposed effluent-free mills are based upon (TMP, CTMP, PGW) are all highly automated low-labour systems, with established track records.

The above mentioned zero-effluent mechanical pulp mills are all designed to produce market pulp, which normally implies stringent quality requirements. In the case of the Ontario mills within the scope of this project, the interest in this technology lies in the newsprint mills, and St. Marys Paper. In these mills, it could be feasible to apply the above mentioned technology to replace all pulp production on site. The toxic substances generated, or released from the wood, in the pulping operation would be recovered for incineration, except for the quantities carried over with the pulp into the paper mill.

Several publications in the early and mid 1980s discussed the possibility of operating newsprint mills with sufficiently small effluent volumes for evaporation or other concentrating process to be applied, and the concentrated effluent incinerated. They generally concluded that some form of washing of the pulp would be required to control the concentration of dissolved solids in the paper machine wet end to acceptable levels.

The traditional drum washers used widely in the kraft industry cannot be used effectively with newsprint grades of pulp due to the much slower drainage characteristics. Press washers have been investigated frequently, but the limitations on performance of such a device which relies on simple dilution and re-thickening restrict the ability to wash pulp effectively without generating excessive quantities of filtrate.

The two zero-effluent BCTMP mills mentioned above use recently developed screw presses as pulp washing devices which include the innovative capability to perform some displacement washing as well as simple dilution/thickening.

This appendix examines the feasibility of applying the above technology to Ontario's newsprint mills in light of recent developments.

1.3 Technical Feasibility in Ontario

1.3.1 Newsprint with 100% TMP

Although there are no mills in Ontario manufacturing newsprint without some chemical pulp reinforcing, it is established that this is technically feasible.

100% TMP newsprint made from different wood species is presently being produced commercially. Table E.2 shows a list of several newsprint mills that produce newsprint using 100% TMP. The wood species used are spruce, balsam fir, pine and small amounts of other softwoods and hardwoods.

The softwood species of Ontario are: White spruce, black spruce, balsam fir, jack pine, eastern larch and hemlock (Isenberg 1980). All these wood species would be suitable for newsprint from 100% TMP.

However, as shown in Table E.2, spruce produces the strongest TMP sheet followed by balsam fir, jack pine and larch. The newsprint mills listed in Table E.2 all use large amounts of spruce chips. It has been shown that up to 20% jack pine can be used in the chip furnish without significant effects on the strength - energy relationship (Laliberte 1987).

For production of a 100% TMP sheet, strength is the limiting pulp property. Addition of kraft pulp or chemical treatment of chips or pulp in the TMP mill can be used to enhance the strength properties of the newsprint sheet. However, this will have a negative effect on the optical properties of the paper.

Table E.2 Strength properties for TMP from different wood species

Mill	Raw material	CSF	Tensile	Burst	Tear	Reference	Start-up
Domtar, Donnacona Quebec	60% black spruce	100-150		2-2.6	8-9.5	Mercier 1988	
	35% balsam fir						
	5% jack pine						
Domtar Dolbeau Quebec	spruce					Laliberte 1987	1987
	jack pine (up to 20%)					Rodden 1988	
F.F. Soucy Inc. Riviere-du Loup Quebec	80% balsam fir	125		2-2.4	8.5-9	Bastien 1983	1976
	20% spruce						
Donohue-Clermont, Quebec	spruce					Rodden 1988	1985
	balsam fir					Brussian 1985	
Bowater Liverpool Nova Scotia	70% spruce/balsam					Karl 1988	1989
	10% pine					Stevenson 1990	
	10 % hemlock						
	10% hardwood						
Alberta Newsprint Whitecourt Alberta	50% spruce	120-130		2.1+	9.0+	Sunds info	1990
	50% pine						
Stora Kvarnsveden Sweden	100% Scandanavian. spruce	90-100	36		7-8	Ferritsius 1989	1988
Kotka Mills Finland	100% Scandanavian. spruce	105	34		8	Skinnar 1984	
Bear Island Paper Co Doswell VA	100% loblolly pine					Smith 1980	1979

2 Mass and Energy Balance

The key issue in assessing the feasibility of applying the new zero-effluent technology is whether a satisfactory mass balance is attainable with available equipment. This also provides the basis for costs.

This subsection describes a detailed simulation of the process implications involved in the integration of a new zero-effluent TMP mill with an existing newsprint mill. The objective being to be able to operate the plant with effluent discharges which will be non-toxic, and will carry under 10% of the loading of a normal Ontario newsprint mill which has only primary treatment.

The simulation was developed using the General Energy and Mass balance Simulator (GEMS), a widely used process simulation software package which is optimized for pulp and paper industry processes.[2] This appendix discusses some of the mechanics of the GEMS simulation which are not directly relevant to the process, but which define the calculation procedure.

Two TMP mills have been simulated: A base case TMP mill and one alternative for the zero-effluent TMP mill. The flowsheet for the latter is shown in the appended figure. The base case, conventional mill is similar, but lacks the press washers between refining stages and upstream of the paper machine.

2.1 Fibreline Base Case

The purpose of the simulation was to simulate the base case TMP mill without washing and estimate the amount of dissolved solids in the paper machine white water when 50 m^3/tonne paper machine white water were discharged. The zero-effluent TMP mill was then to be simulated in order to determine the equipment requirement for a 90% reduction of the dissolved solids and of resin acids in the paper machine excess white water compared to the base case with less than 10 m^3/tonne effluent discharged to sewer in the TMP mill.

Resin acids are considered as representing the acute lethality of the untreated effluent from this type of mill.

Both simulations are based on 1.0 tonne pulp produced.

---

[2] *GEMS has been in use for almost 20 years, and is constantly being updated. Engineers responsible for a significant proportion of the more modern mills in North America use GEMS as the basis for their process calculations.*

2.2 Base case TMP Mill Simulation

The base case TMP mill has no washing. Operating conditions are summarized in Table E.3 and the process equipment can be described as follows:

> Presteaming of chips to 60 deg C with blowback steam from the primary refiner; chip wash, presteaming to 100 deg C with blowback steam; plug screw; preheater with possibility to add sulfite, plug screw, primary refiner, secondary refiner, latency chest, screen room consisting of screens, cleaners, rejects press and an atmospheric reject refiner.
>
> A decker thickens the pulp after the screen room. Pulp would normally be stored for several hours prior to feeding the paper machine.
>
> A very simple wet end of the papermachine is also included to estimate TDS (total dissolved solids) and resin acids in the paper machine-white water.

A heat recovery system converting the high pressure TMP steam from the mainline refiners to clean steam is also included, since this would normally be installed in any new or rebuilt TMP mill. The atmospheric steam from the reject refiner and the blowback steam from the secondary refiner is condensed in an atmospheric condenser where hot water is produced.

Table E.3 Operating conditions for base case TMP mill

Chip moisture		50%
Consistency after chip wash drain		35%
Plug screw outlet consistency		50%
Primary refiner	outlet consistency	45%
	specific energy	1.0 MWh/t
	inlet pressure	200 kPa
	housing pressure	400 kPa
Secondary refiner	outlet consistency	40%
	specific energy	0.8 MWh/t
	inlet pressure	120 kPa
	housing pressure	400 kPa
Reject refiner	outlet consistency	40%
	specific energy	0.8 MWh/t
	inlet pressure	101 kPa
	housing pressure	101 kPa
Reject rate	screen	30%
	primary cleaner	25%
	secondary cleaner	25%
	tertiary cleaner	5%
Rejects press consistency		30%
Decker outlet consistency		8%
Fibers in TMP white water		0.01g/l
Make-up PM white water to TMP		16 m^3/tonne
PM white water discharged to sewer		25 m^3/tonne
Headbox consistency		0.3%
Paper machine press discharge consistency		42%

TMP white water is used for refiner dilution. No seal water leakage in refiners (new refiners).

The total yield loss is assumed to be 4% i.e. 40 kg/tonne. The dissolved solids are divided into three different stream components: resin acids, volatiles and other organics. The dissolution of wood is distributed in the mill as shown in Table E.4.

Table E.4 Dissolution of organics in TMP mill

Process	Resin acids	Volatiles	Other org.	Total
Atm. preheater	0.0	0.0	3.0	3.0
Preheater	0.0	0.0	3.0	3.0
Primary refiner	0.36	1.8	27.84	30.0
Secondary refiner	0.04	0.2	3.76	4.0
Reject refiner	0	0	0	0
Sum yield loss	0.4	2.0	37.6	40.0

These assumptions are valid for TMP from spruce.
All data expressed as kg/tonne

All volatiles are assumed to leave with the flash steam from the refiners.

2.3 Zero-effluent Case

The process flowsheet for the zero-effluent TMP mill shown in the appended figure differs from the base case in two ways:

Interstage washing between primary and secondary refiner (displacement washing screw press)
Post washing after decker (1-3 displacement washing screw presses)

The assumptions for the process conditions are the same as for the base case containing the chip wash, refiners, screen room, papermachine, heat recovery and yield loss.

The following assumptions are made for the displacement screw presses:

Table E.5 Operating conditions in displacement screw press

Inlet consistency:	5%
Intermediate consistency:	15%
Discharge consistency:	30%
Fiber in press filtrate:	0.1%
Fraction of pulp displaced:	90%
Shower water on last press:	2.3 m^3/tonne (dilution factor 1)
K-factor (washing efficiency factor) assumed were as follows:	
Resin acids	0.70
Volatiles	0.98
Other organics	0.98

Source: Egenes and Barbe 1990.

The K-factors suggested in this paper are 0.70 for DCM extractives and 0.98 for dissolved solids. In the simulation K=0.70 has been used for resin acids since they are a type of extractives and K=0.98 for volatiles and other organics. However no volatiles will be present in the pulp streams since all volatiles are assumed to leave the refiners with the flash steam.

2.3.1 Yield loss and extractives

The total yield loss as dissolved solids is assumed to be approximately 40 kg/tonne. In the simulation the dissolved solids are divided into three components:

Resin acids
Volatiles
Other organics.

The dissolved organics consists of lignin carbohydrates, extractives and other substances.

The most troublesome component in the dissolved solids are the extractives. The extractives have the following characteristics:

More difficult to wash out of the pulp (Egenes 1990 and Wearing 1983) than other dissolved organics
Contain resin acids which correlate well with the toxicity of the mill effluent (Wong 1979 and 1980)
Cause pitch problems in the mill (Allen 1980)
Negative effects on the product quality

Table E.6 Amount of extractives originally in the wood depending on wood species

	Extractives %	Reference
White spruce	2.0	(Isenburg 1980) Alcohol-benzene extr.
Black spruce	2.2	(Isenburg 1980)
Norway spruce	1.7	(Sjostrom 1981)
Balsam fir	3.2	(Isenberg 1980) Alcohol-benzene extr.
Jack pine	4.0	(Isenberg 1980)
Scots pine	3.5	(Sjostrom 1981)

The extractives in the wood are measured by extraction of the wood with a solvent for example dichloromethane (DCM-extractives), ether or alcohol-benzene.

In the wood, the extractives exist in (Sjostrom 1981):

Resin canals
Encapsulated in parenchyma cells

For spruce (Norway spruce) 45% of the extractives are located in the resin canals compared to 70% for pine (Scots pine). The extractives in the resin canals are more easily dispersed during pulping then the extractives in the parenchyma cells. However during refining, part of the parenchyma cells are crushed and some parenchyma cell - extractives dispersed (Allen 1980).

The extractives in the resin canals for spruce wood (Norway spruce) have the following composition: 50% resin acids, 20 to 30% volatile monoterpenes and 20 to 30% terpenoids and fatty acid esters. Pine contains a higher amount of resin acids, 70% to 80% of the extractives in the resin canals (Sjostrom 1981).

The extractives in the parenchyma cells consist of fatty acid esters and sterols (no volatiles).

From this it can be estimated that the amount of volatiles in spruce wood is approximately 2.0 to 2.5 kg/tonne and for pine 5 to 8 kg/tonne. The amount of resin acids can be estimated to 4.5 kg/tonne for spruce and 20 kg/tonne for pine.

The actual amount of resin acids dissolved during refining was measured by Wong (1979) and by Breck (1983). It was found that for black spruce/balsam fir chips an average of 400 g/tonne resin acids were dissolved during two stage refining. 600 g/tonne resin acids were dissolved for jack pine chips. The largest part, 90 to 100%, of all components were dissolved in the first refiner stage.

2.3.2 Balance with open paper machine

After the base case balance was calculated, various combinations of washing equipment and wash liquor flows were investigated. The best alternative investigated with respect to effluent reduction was the configuration shown in the appended figure.

These balances indicated that even with the three modern design press washers and an interstage washing stage, that 47% of the total resin acids in the raw material would be discharged from the paper machine, in a flow of approximately 50 m^3/tonne. The remaining 53% of the resin acids would be concentrated in 6.6 m^3 of pulp mill effluent/tonne. The incremental effect of additional presses is minor. It is not feasible to increase the press wash liquor flow beyond the 3 m^3/tonne pulp that was used, because of the practical limitations of the equipment.

2.4 Balance with Closed Paper Machine

There were no detailed balances calculated for the scenario where the paper machine system would be sufficiently closed for all white water to be used as wash liquor. The mass balance would be quite simple, since all the resin acids and BOD causing substances would be contained in the pulp mill effluent. There are major practical difficulties in lowering the paper machine effluent volume to the range where concentration and incineration becomes worth investigating. Detailed analysis of this is beyond the scope of this project, but one can observe that the Hylta newsprint mill in Sweden (refer to appendix C) operates with 12 m^3/tonne effluent. This is lowest newsprint mill effluent flow known to the authors, and is probably the lowest in the world. Effluent at Hylta is treated biologically, but could potentially be treated by concentration and incineration. As indicated below, the costs would be considered excessive by normal standards, so the only reason to do so would be to totally eliminate effluent.

2.5 Concentration and Incineration of Effluent

2.5.1 Evaporation

A wide variety of evaporation equipment has been used in industry for many years to concentrate liquids comparable to the concentrated wastewaters which would be discharged by a mechanical pulp mill designed for minimum effluent flow (Burke 1990). The authors do not expect that there are likely to be any insurmountable technical problems, subject always to the caveat that full scale experience is required to demonstrate any technology.

Discussions with those having operated pilot plants evaporating effluent from high-yield pulping processes indicate that the maximum practical concentration is approximately 50%, primarily because the liquors become excessively viscous at higher concentrations. The liquors would be auto-combustible at these concentrations.

The condensates from the evaporators would be contaminated by volatile organics, and may require treatment prior to reuse. The non-condensible volatiles can be incinerated readily, using technology which is widely used in the kraft pulping industry.

2.5.2 Freeze crystallization

Freeze crystallization can be used to recover relatively pure water from streams with several percent dissolved solids. Existing applications include seawater desalination. The principle is that when ice crystals form in water, they contain little or no dissolved solids. They can be removed from the water, and melted; providing clean water, and leaving the original contaminants in a concentrated form.

In practical industrial systems, feed liquor is cooled in the tube side of a shell and tube heat exchanger with ammonia evaporating in the shell side. Ice crystals form and are removed from the circuit by floating to the top of a quiescent tank, and being raked off to a melting vessel. The ice is virtually pure, provided that the concentration of contaminants in the liquor is not excessive. The ice crystals are melted with warm water, heated by the ammonia cooler or other waste heat in the refrigeration system. The gasified ammonia is compressed and condensed in a classic refrigeration cycle. Other refrigerants could be used, but ammonia has been widely used in industry for many years.

There is currently only one vendor known to the authors offering freeze crystallization for concentration of effluent from mechanical pulp mills (HPD Inc., Napierville, Illinois).

The practical limit of concentration by freeze crystallization appears to be 15% to 20% for CTMP and similar pulping waste liquors. Fatty and/or resin acid contamination of the ice is the limiting factor. Sodium salts do not crystalize until the concentration is raised further. Feed liquor should contain under 60 mg/L suspended solids, although up to 150 were processed successfully in the pilot plant. Purity of the recovered ice is the limiting factor (Personal Communication, P. Stewart, HPD, Napierville, Illinois).

2.5.3 Liquor Incineration

The concentrated liquor from either freeze crystallizers or evaporators could be burned in a variety of equipment, since the inorganic content would be very low relative to the traditional spent pulping liquors.

The recovered liquor would have a heating value and water content similar to bark, and could probably be burned in the mill's bark boiler, if capacity is available.

3 Cost Estimates

3.1 Freeze Crystallization

Based on the freeze crystallization technology being used at the Chetwynd, BC mill, the capital costs of a system to concentrate 12m^3/tonne effluent from newsprint mills of various capacities are estimated as follows:

Capacity tones/day	Capital Cost $	Annual Operating Cost $
400.	33,220,000.	1,987,000.
500.	37,979,000.	2,379,000.
600.	42,370,000.	2,765,000.
700.	46,476,000.	3,145,000.
800.	50,352,000.	3,522,000.
900.	54,040,000.	3,896,000.
1,000.	57,566,000.	4,267,000.

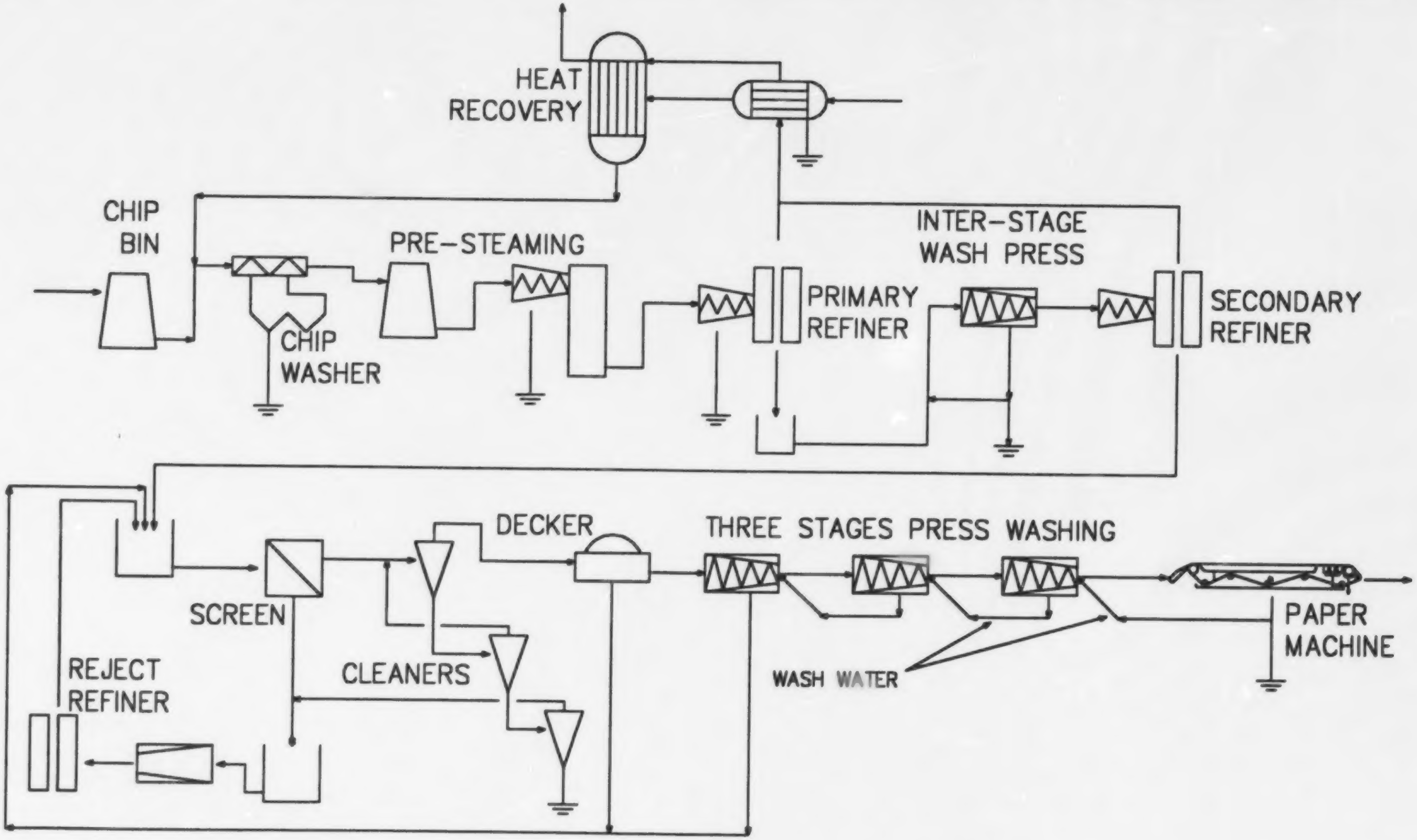
Above costs assume total mill process effluent flow of 12 m^3/tonne product

3.2 Overall mill

Superficially, the above mentioned costs appear to be attractive in relation to the costs presented in Chapter 8 of this report for several of the Ontario newsprint mills. However, they are predicated on the installation of a completely modernized TMP mill at a cost in the order of $200 million for 1000 tonne/day capacity, or $140 million for a capacity of 500 tonne/day. Such a mill would discharge approximately 25 kg BOD/tonne pulp. It would be possible to treat such effluent biologically to lower BOD to under 1 kg/tonne product for substantially lowers costs than are indicated above. For example, the activated sludge system at Alberta Newsprint discussed in Appendix C is reported to have cost $15 million for the 700 tonne/day mill. Note that the Iroquois Falls mill discharges approximately 65 kg/tonne of product, which is the principal reason for the high effluent treatment costs indicated in Chapter 8 for this mill.

To summarize, this initial hypothesis of modifying a TMP mill so that the pulp being supplied to the integrated paper mill would be sufficiently uncontaminated to permit discharging the paper mill effluent without treatment proved to be technologically impossible.

If the total newsprint mill effluent is integrated with the TMP mill process, then it may be possible to operate the mill with sufficiently low effluent flow to make concentration/incineration practicable. However, this would require that the effluent flow from the newsprint machine(s) and their auxiliaries be reduced to a few cubic metres per tonne. It is generally accepted that this is impractical for an existing operation with currently known technology. Even if it could be accomplished, the costs of concentration/incineration are considerably higher than traditional biological treatment.


HEAT RECOVERY
CHIP BIN
CHIP WASHER
PRE-STEAMING
PRIMARY REFINER
INTER-STAGE WASH PRESS
SECONDARY REFINER
SCREEN
CLEANERS
DECKER
REJECT REFINER
THREE STAGES PRESS WASHING
WASH WATER
PAPER MACHINE

Flowsheet for TMP/Newsprint Mill with Interstage and Post-refiner Washing

Appendix F

Use of Municipal Sewage as Mill Water Supply

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Feasibility of Using Treated Municipal Sewage as Mill Makeup Water

SUMMARY *At least six pulp and paper mills are using Treated Municipal Wastewater (TMW), one in Mexico, two in California, and three in South Africa. TMW is used in areas where little opportunity exists for direct contact between workers and the treated wastewater. TMW is disinfected to a predetermined standard. Where direct contact is expected, a higher standard of disinfection is used. The water is carefully segregated into separate piping systems and is clearly labelled. The TMW may not be used in the finished product areas (paper and pulp machines) because of quality control concerns which would depend on the requirements of the markets served. No adverse health impacts associated with these operations have been reported.*

Conclusions

The technology of using treated municipal wastewater (TMW) as part of the process make-up water in pulp and paper operations is proven technology as demonstrated by the six applications currently in service. TMW should not be added as a blend to regular process water, but should be added to the system in selected areas.

To apply this technology in Ontario, would require that a mill be located close to a major population center. Primary, secondary, and tertiary wastewater treatment of the municipal wastewater is required. There are some opportunities in Ontario where TMW could become part of the mill make-up water supply. The driving force for carrying out such projects appears to be a shortage of water. Since it is not a technology that is targeted at upgrading the effluent from pulp mills, it is not considered as a part of any technology train.

Introduction

The notion that an abundant supply of clean water will always be available at minimum cost is today being challenged. Water conservation measures are being applied both in the public and private sector. Pulp and paper industry water use has been reduced 30 percent during the past decade (Minor 1991).

An equivalent water saving can be realized by water reutilization. The purpose of this appendix is to describe a simple example of how one bleached kraft pulp and paper mill plans to reutilize treated municipal wastewater as make-up water, required for mill operations.

The need originated when the City of Tacoma, WA recognized its water supply source was not adequate to serve both the mill's and the expanding community's future needs. A conventional solution would have required an expensive long distance pipeline, so the possibility of the reutilization of municipal treated effluent was investigated.

Current Status of Water Reutilization in Pulp/Paper Industry

At least six pulp and paper mills are currently using treated domestic wastewater in their process operations. These are:

Garden State Paper, Pomona, California
Simpson Paper, Pomona, California
Paperiera Moldonado, Monterrey, Mexico
Enstra mill of South African Pulp and Paper Industries Ltd., Springs, South Africa
Mondi Paper Company, Durban, South Africa
S.A. Board mill, Belleville, South Africa

Description of reutilization program at other mills

Garden State Paper has been using treated wastewater from the Pomona, California sewage treatment plant since 1980 (Yulke 1981). In 1984 (Harding 1984) reclaimed water accounted for 96 percent of process water use in the mill. Process water is used in the pulping of recycled paper, making newsprint, and for cooling electrical equipment. Mill employees (130) are exposed to process water in cleaning operations when wash water commonly stands on the floor of the process areas. The reclaimed water is given tertiary treatment by the City of Pomona resulting in low TSS (2 mg/L) effluent with a coliform count of 2/100 ml and a chlorine residual of 4 mg/L. The reuse/process water piping in the mill is colour coded, and signs distinguishing between potable and nonpotable water in the mill are prominently displayed. No record of adverse health impacts of the reclaimed wastewater can be found in the literature.

The Simpson Paper Company San Gabriel mill, Pomona, California has been using reclaimed wastewater from the same Pomona wastewater reclamation plant, as described above, since 1984 (Yulke 1981). The reclaimed water is mixed with water from potable and private well water supplied for general process uses, wash down, and cooling. Treated wastewater introduced into the plant is of high quality (e.g. <2.2 MPN/100 ml) as described above. Mill workers (525 employees) are exposed to process water in the form of mists, drying vapors, and wash down water resulting from papermaking and general cleanup. Potable water piping is much smaller than process water piping and is generally identifiable by size. Exposed piping is also prominently labeled. No record of adverse effects of water use in the mill has been found.

In South Africa, treated municipal wastewater has been used for process water supplement in two paper mills and a liner board mill since the early 1970's (Oderdall 1979). In 1979, the Enstra mill of **South Africa Pulp and Paper Industries Ltd.** near Springs, South Africa used 25,000 m^3/day of reclaimed wastewater with 16,000 m^3/day of potable water to satisfy general mill water needs. Brightness requirements dictated the use of chemical coagulation and flotation as an adjunct to the original plain rapid sand filtration of the Spring's secondary effluent.

The **Mondi Paper Company mill** at Durban, South Africa, produces newsprint and fine paper grades, and has used reclaimed Durban municipal wastewater since 1972. The combined sources are used throughout the mill.

The **S.A. mill** at Belleville, South Africa has used reclaimed municipal effluent to satisfy about two-thirds of its process water need. The mill produces gray and manila-backed board (both coated and uncoated) at 71 tonnes per day. No indication of adverse health impact associated with the wastewater reuse is reported (Oderdall 1979).

Water safeguards for reutilization

Regulatory requirements applicable to wastewater reuse in industry where little opportunity exists for direct contact between workers and the treated wastewater are generally based on providing disinfection to meet defined levels of microbiological quality. However, where direct contact is expected, a higher standard of microbiological quality is used requiring filtration followed by carefully controlled disinfection. The resulting effluent can be relied upon to pose no significant risk to wastewater users. The important elements of a program to effectively control the reuse of wastewater to ensure safety would include:

> treatment of the municipal effluent including filtration and disinfection to maintain coliforms at <2.2/100 ml
>
> maintaining the reliability of the treatment system including continuous monitoring of turbidity and (chlorine) disinfectant residual tied to an alarm and control system to prevent delivery of unacceptably treated product
>
> a carefully designed program of piping segregation, marking, and worker education to prevent unintended potable use.

Reuse, even where incidental human contact occurs, can be implemented without contributing to increased incidence of illness. Risk associated with exposure to chemicals in reclaimed municipal wastewater is significantly lower than the controllable risk of infection. Review of experience in the reuse of municipal wastewater, specifically in the pulp and paper industry, shows that this can be accomplished economically without compromise of either product quality or worker health and safety.

Plan at Simpson, Tacoma

The Simpson, Tacoma mill produces approximately 1,200 tonnes/day of kraft pulp for linerboard, heavyweight paper, and market pulp. Approximately 360 tonnes/day is bleached for use as white top liner, heavyweight white grade, and market pulp. The mill process includes a continuous digester, brown stock washing, D_cED high substitution bleaching, a full kraft recovery cycle, two paper machines, and one pulp dryer. The mill's effluent treatment includes primary clarification, UNOX activated sludge, and secondary clarification.

The Simpson, Tacoma kraft mill uses 120,000 m^3/day of potable water from the City of Tacoma for process needs. This water is distributed through the mill by process area as shown in Figure F.1. The three categories of use types are:

Process: This includes all process water usages such as showers, consistency control, stock dilutions, boiler feedwater, etc. Water is generally not sewered after initial use, but carried on to the next process step. Quality requirements can vary widely depending on both the mill process area and type of usage.

Cooling: reuse to process: This category includes heat exchanger and equipment cooling, pump seal and gland water, as well as miscellaneous flushing water that ends up in the process. Water quality requirements for cooling applications must be met for the initial usage plus evaluation must be made of downstream user requirements.

Once through to sewer: Some of the fresh water that enters the mill is used once and sent directly to sewer. An example of this is water used for scrubbing of non-condensable gas which is directly sewered from the causticizing and lime kiln area. Much of the water used for cooling of bearings, seals and other miscellaneous heat exchangers is difficult to collect because of the large number of use points. The amount of water directly sewered in this manner is tabulated by process use and amounts to approximately one-fourth of the fresh water intake.

Water quality concerns

Because of the variety of uses in the Simpson mill, no single standard or specification can adequately cover the mill's needs. Rather than develop a standard, each mill process area was reviewed to identify any special concerns. Typical operating problems that can result from reuse of municipal effluent include:

increased slime growth
increased corrosion
scaling
wire, felt and shower plugging
brightness losses
staining (NCASI 1976, NCASI 1985).

Paper and pulp machines: As most of the water used here will come in contact with the virtually finished product, water quality concerns center around its effect on the product. These raised the following questions:

> Nutrients. Will increased slime growth occur and degrade product quality? Can biocides be used to keep this under control at a reasonable cost?
>
> Colour. Will product staining and brightness losses occur?
>
> Suspended solids. Suspended solids buildup can be troublesome due to the large numbers of showers, orifices, and other small openings in the machine area equipment.

No. 3 and No. 4 recovery: Water usage in these areas is mostly for miscellaneous cooling and is generally sewered after first usage. Water that meets cooling water guidelines should be acceptable; i.e., a non-corrosive, stable (non scale-forming) water source is required as a minimum. Suspended solids must be eliminated to avoid plugging small bearing cooling orifices.

Caustic/lime kiln: Similar to the recovery area, most water is used for once-through cooling application. Water that ends up in the process is used for flushing dust in the No. 1 and No. 2 kiln hoppers. This water ends up in the white liquor, which, when returned to the digesters, completes the kraft recovery cycle. Because this is part of a closed loop, water quality concerns include chlorides and other dissolved salts that could build up to unacceptable levels.

No. 1, No. 2, and No. 4 evaporators: In these areas, nearly all of the fresh water used ends up in the process. Initially, the water must be acceptable for cooling water usage, then it is recycled to the paper machine, bleach plant, and brownstock washing. Water quality requirements for these secondary usages vary, and are discussed under the appropriate process area.

Boiler feedwater: Boiler feedwater is subject to stringent quality requirements. Chief parameters of concern include iron, copper, silica, and total dissolved solids. Iron and copper are a particular problem as removal is not provided by the existing feedwater treatment. Total dissolved solids can be removed by the existing demineralizers, but any increase will result in increased operating costs. Fouling of the demineralizer resins by trace organics is also a potential operating problem.

Boilerhouse auxiliary: Fresh water in this area is used for miscellaneous cooling and pump seals. Since the water is sewered after first usage, water that meets cooling water requirements should be sufficient.

Bleach plant: In addition to cooling and general process quality requirements, water quality concerns in the bleach plant include metal ions which can interfere with the bleaching process, organic precursors which can result in dioxin, and carryover to the paper machine and pulp machine areas. More than ninety-five percent of the water use in the bleach plant ends up in the process.

Washing and screening: 36 percent of the water used in the washing and screening area is not recycled. Cooling water guidelines provide minimum standards for this process area. In addition, because some of the water used ends up in process streams which end up in the recovery area, hardness and dissolved solids levels are also a concern.

Dewatering: Almost all of the water used in the dewatering area is sewered. No special concerns are apparent beyond typical cooling and process water guidelines.

Characterization of water

A detailed comparison of water quality characteristics was carried out for the Tacoma secondary effluent and several mill process water streams. Comparison was also made to secondary drinking water standards, which were developed to protect the public from nuisance and aesthetic concerns, and typical cooling water guidelines. Reported water quality from NCASI studies of fine paper mills were compared with the city effluent. A summary of key treatment objectives, including individual goals and rationale, is presented in Table F.1.

Table F.1 Key treatment objectives

Parameter	Goal	Reason
Total coliforms	Reduce to below detection (<2.2 mpn/100 ml)	Protect human health
Colour	Reduce to below 25 colour units	Preserve product quality
TSS	Reduce to below 5 mg/L	Reliability and improved disinfection efficiency
Phosphorous	Reduce to less than 1 mg/L	Reduce nutrient supply
Copper	Maintain below 48 ppb	Stringent NPDES permit

Treatment of waters for reuse

The simplest treatment option consists of direct filtration followed by disinfection. This should meet requirements for coliform and removal of residual suspended solids. Unit processes include wastewater pumping, gravity filtration disinfection with chlorine, and treated wastewater pumping at the Simpson mill.

Due to concerns over the colour and increased slime growth from nutrients, reclaimed effluent will not be recycled to the paper machine and pulp machine areas. Because most used water goes to the sewer, and because process uses are not particularly water quality sensitive, reclaimed effluent could entirely replace fresh water in the recovery and causticizing areas. In the boilerhouse, reclaimed effluent will not be substituted for boiler feedwater because of stringent water quality requirements and potential organic fouling of the mill's demineralizers. Auxiliary uses in the boilerhouse, include pump seal water and cooling water which can be replaced by reclaimed city effluent. Reclaimed effluent will not be used in the bleach plant because of potential carryover to the more sensitive paper and pulp machine systems. Reclaimed effluent is used in washing and screening and dewatering due to lesser sensitivity in waste quality needs. Table F.2 shows direct reuse will be 27,600 m^3/day. A treatment capacity of 40,000 m^3/day was selected with an additional 12,400 m^3/day being reused via evaporator cooling. This makeup eventually flows to more water quality sensitive parts of the mill; however, it will be diluted with large volumes of fresh water, and the resulting water quality may be adequate. A number of issues were identified which will require additional investigation, generally to confirm assumptions. They include:

> **Laboratory test program**: These tests will investigate colour and phosphorous removal by alum coagulation of the Tacoma effluent. Tests will also be run to evaluate slime control alternatives.
>
> **Handsheet investigation of colour requirements**: Handsheets will be made utilizing various blends of freshwater with both treated and untreated Tacoma effluent. This will allow correlation of brightness losses or improvements with degree of treatment and percent blend of recycled effluent. The amount of reuse in pulp and paper machine areas can be fully evaluated.
>
> **Development of detailed reuse flow scheme and mill water balance**: Preliminary design of the reuse distribution header system. The details of how to best tie into the approximately 70 individual services in the mill will be developed. Knowledge of further uses after initial tie-in needs will be reviewed.
>
> **Preliminary design of reuse treatment**: An engineering study of site alternatives and development of site plans, general arrangements, and process flow diagrams, as well as more refined cost estimates will be developed.
>
> **Evaluate instantaneous plant capacity versus increasing storage costs**: Minimum hourly flow of Tacoma treated wastewater is approximately 36,000 m^3/day. Average daily flows are about 80,000 m^3/day. Flow equalization could be utilized to allow reuse of higher effluent flows. The necessary storage facilities and plant capacity are economic tradeoffs requiring further evaluation.

Mill NPDES permit revisions: The current mill effluent permit is due for renewal. Permit changes will be negotiated to provide the mill with credits for pollutants transferred to the mill in Tacoma effluent.

Submittal for Food and Drug Administration (FDA) Approval: The FDA will investigate the potential reuse of treated municipal wastewater because the mill's product is used in food packaging. Based on wastewater data and reuse schematics in the submittal package, FDA chemists will prepare and evaluate worst-case scenarios.

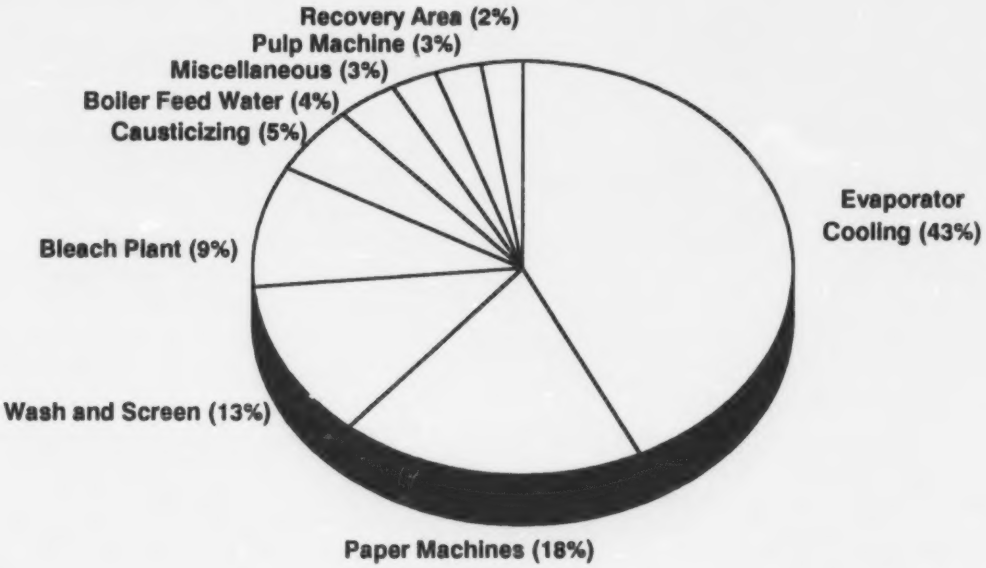

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Figure F.1 Water usage by process area

Table F.2 Breakdown of reuse utilization

Mill service	Direct freshwater usage m³/day	Reuse alternative 40,000 m³/day
Paper machines	22,000	0
Pulp machines	3,200	0
Recovery	2,800	2,800
Causticizing	6,400	6,400
Evaporator cooling	51,200	12,400
Boilerhouse auxiliary	2,400	2,400
Bleach plant	11,200	0
Washing and screening	15,200	15,200
Dewatering	800	800
Total	120,000	40,000
Use breakdown:	---	27,600
Total direct usages (w/o evap. cooling)	---	
Total indirect usages After evap. cooling	---	12,400
GRAND TOTAL	---	40,000

Water used in evaporator cooling enters the warm and hot water system and is subsequently reused in washing and screening, bleach plant and paper machines.

Appendix G

Other Effluent Control Technologies

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Introduction

A considerable number of technical solutions to the problems of reducing mill effluent discharges have been proposed and promoted over the past twenty years. Knowledgeable readers will notice that some well-known processes are not mentioned in the body of the report. The processes omitted were considered to be unsuitable, unproven, ineffective, or inapplicable in Ontario mills or **simply equal to other technologies in performance but without any clear economic advantage**. Some are discussed below, and the authors wish to emphasize that omission from the list of "demonstrable technologies" does not necessarily imply that the authors recommend that the processes should be rejected by Ministry of the Environment approvals staff if a company considers that they are suitable for their particular situation and presents credible evidence of their capabilities.

Effluent Prevention at Source

Prenox

The principle of the Prenox process is to treat the pulp with nitrogen dioxide so that it can be subsequently delignified with oxygen to a lower Kappa number than with conventional oxygen delignification, while preserving pulp quality. A pilot plant was operated, apparently successfully, in Sweden in the mid 1980's but the promoters have not sold a full scale system. As indicated in the report on the Aspa mill in Appendix C, the capital cost was estimated to be $40 million for a 500 ADt/day capacity Prenox system, with operating costs of $16/tonne pulp.

The Prenox process has been described by Simonsson (1987), Brannland (1990), and Samuelson (1990). This process requires lowering the pH in the middle of an alkaline fibre line which can cause complications and requires the addition of chemicals which would not otherwise enter the chemical recovery system. There have been some difficulties involving the use of NO_2 for the purpose of lowering the lignin content and these have been investigated by Samuelson.

There are concerns that the addition of nitrogen compounds will lead to an increase in NO_x components in the recovery stack gases because the point of addition in the pulping process will result in residual chemicals being introduced to the chemical recovery cycle. There are concerns about nitrated phenols, and other organics.

The Prenox process may have a useful place in the modification of kraft mills to lower the AOX in effluent, but there are no commercial applications and the only data in the public domain are from the developers/promoters. The authors consider that Prenox has been by-passed by developments in extended cooking and oxygen delignification, and have not considered it as a proven, relevant process for the Ontario mills. As discussed in Appendix C, Prenox was evaluated and rejected at the Aspa mill.

Pre-chlorination E_o

The addition of oxygen to the first extraction stage is common for bleached kraft mills. The key to allowing the addition of oxygen at this point is availability of efficient mixers. It is a low cost change that has a positive impact on costs, capacity, and effluent quality. A variation of this application is positioning an extraction stage in front of the chlorination stage.

The installation of a pre-penetration tube along with an efficient mixer ahead of the chlorination stage allows an operation to provide a low level oxygen delignification step. The reduction in molecular chlorine consumption remains as the main advantage. However, in this position it also permits the mill to use a second control point for the bleach plant incoming Kappa No. so that the bleach plant operates at a more uniform production rate. Steady operation is an important factor in environmental performance as well as in maintaining pulp quality.

The pre-chlorination E_o treatment has the advantages of low capital costs, a significant reduction in AOX, and will allow a higher degree of substitution. The disadvantages include higher operating costs, no solids recovery, a second washer may be required, and a chemical imbalance occurs ($NaOH/Cl_2$). Nevertheless, it is a quick short term solution.

Chlorine monoxide bleaching Monox L

Monox L is hypochlorous acid plus a nitrogen based additive which provides cellulose protection. *Monox L* requires the same conditions as chlorine dioxide. Time, temperature and pH ranges are identical as are the metallurgy and pulp/chemical and mixing requirements. It's use has been advocated for replacement of chlorine dioxide in the D_1 stage so that the displaced chlorine dioxide can be used to increase the level of substitution in the chlorination stage. Reduction of dioxins are accomplished without increasing the capacity of the chlorine dioxide plant. The physical properties of the pulp for softwood are slightly inferior, chloroform is still produced in the stage and there is no dramatic AOX reduction (Galluch 1988). The process has not been widely accepted. Two or three mills are using it to assist in the caustic chlorine balance. The pulp produced is used in-plant.

Condensate stripping

The contaminated condensates from the multiple effect evaporators and digesters are frequently steam stripped to remove TRS and BOD. Some mills have used air stripping or waste gas stripping to reduce energy consumption. Some of the older steam stripping systems required one tonne steam per tonne of pulp for effective operation, which represents about 15% increase in purchased energy costs for a typical bleached kraft mill. The recent developments in steam stripping have concentrated on reducing the energy consumption of this process, since many of the systems installed in the 1970's have proven to be excessively expensive to operate at their design efficiency.

Despite the proven capability of condensate strippers to reduce effluent BOD and toxicity, a stripper is often very inefficient economically as an environmental protection measure. The first reason is that most of the "low molecular weight" compounds which are removed can be removed biologically at much lower cost.

Allowances for stripping condensates in the effluent treatment systems evaluated in this report have not been included, since most mills with effective odour control programs already strip condensates. In any mill without an effective odour control system, the biological treatment system itself will be a minor contributor to total mill odour.

Sulphur dioxide treatment of chlorination effluent

The effluent from the bleach plant chlorination stage is one of the principal sources of toxicity to fish in most bleached kraft pulp mills. It has been shown that if residual molecular chlorine is stripped from the chlorination stage effluent, the pH raised to 5.5 and about 0.02% sulphur dioxide added, the effluent toxicity will be substantially decreased or eliminated. The work performed indicates that the performance of this treatment process varies between mills and wood species, as with most effluent treatment processes, and that it is essential that the unbleached pulp be washed effectively prior to bleaching. This process was used successfully for a short time in the 1960's, and received renewed attention in research in the early 1980's (Betts 1966, Donnini 1981, 1983a, Donnini 1985). The authors have not included it in any of the alternative technology trains, since all include efficient biological treatment, which would make the sulphur dioxide treatment redundant.

Rapson process and zero effluent mills

The Rapson process (Great Lakes FP 1980 and McCubbin 1984) appeared to offer the possibility of a zero-effluent mill. It is based on extensive recycling of the bleach plant process water, and the use of all bleach plant effluent for brown stock washing, so that all organic matter removed from the pulp during bleaching would be incinerated in the recovery boiler. This could eliminate the discharge of organochlorines, including dioxins, but there are no data available on the quantities of dioxins in the recovery boiler stack gases, if any.

It is now clear that it will be impracticable to operate a mill using the Rapson process closed cycle, due to the build-up of metals in the process, but the possibility of destroying a high proportion of bleach plant organic wastes by incineration has some obvious environmental advantages.

A full scale system was installed in the Thunder Bay mill in the 1970's, but had to be abandoned after several years due to a variety of reasons including corrosion. The Rapson process is not concluded to be proven technology. In recent personal contacts, two of the key engineers involved with this attempt at operating a closed cycle kraft mill, Dr. Howard Rapson, and Dr. Douglas Reeve both stated that they do not recommend attempting to revive the technology.

Two mechanical pulp mills are due to start-up in early 1991 and early 1992. If these are clearly successful, then they may encourage renewed interest in attempting to build an effluent-free kraft mill.

Other External Treatment Processes

Oxygen activated sludge process

In the early 1970's, Union Carbide Corporation introduced a variation of the activated sludge process where gaseous oxygen is used instead of air to maintain the necessary dissolved oxygen concentrations in the biological reaction vessel, and several vendors now promote this approach with a fair degree of commercial success. Many claims have been made concerning improvements in performance with oxygen vs air, mostly by vendors of oxygen or oxygen-based treatment systems. In our opinion, the considerable additional cost of oxygen is generally not justified, since the existing systems have not demonstrated superior performance to that exhibited by a well designed air activated sludge treatment system. Most of the independent reports of investigations comparing air and oxygen activated sludge in the pulp and paper industry, conclude that the oxygen systems do not demonstrate any performance advantages to justify their additional costs. Examples of these include Buckley (1981) and Rempel (1991).

The main advantages of oxygen AST is that the reactor is covered, so that odor and foam can be readily controlled. This advantage will be tempered in some situations if the lower heat loss associated with the covered systems requires the installation of effluent cooling towers. This may be significant in urban locations.

The higher dissolved oxygen residuals in the aeration basin provide a driving force allowing oxygen to penetrate further into clumps of MLSS biomass thereby maintaining a more aerobic biomass than is possible for conventional AST. The higher dissolved oxygen residual mentioned above becomes significant only for high F/M loaded aeration basins. Within recent years the industry has begun to recognize that a more conservative F/M loading will result in significant activated sludge performance improvements such that the oxygen activated sludge oxygen penetration concept discussed above has become less significant.

Oxidation ditch

The oxidation ditch is a completely mixed extended aeration, activated sludge treatment process which is operated with long solids retention time to achieve sludge stabilization and near complete nitrification to reduce ammonia contaminants. The primary advantage of the oxidation ditch, compared to conventional activated sludge, is the combining of the wastewater treatment and sludge stabilization steps and the resulting simplification of operation.

With the advent of deeper ditches (for optimum land utilization) depth mixing may become inadequate when only using the surface rotor. One equipment supplier (Eimco Corporation) use vertical flow surface aerators and a "water dam" to induce uniform horizontal velocities throughout the entire basin depth to assure adequate mixing in their oxidation ditch which they call a "Carrousel". The key to aeration in this design is matching basin geometry and aerator performance in order to yield an adequate channel velocity for mixed liquor solids transport.

The typical oxidation ditch is constructed in a "race track" configuration consisting of a single channel or multiple connected channels. The Carrousel oxidation ditch system at the Ponderay Newsprint Company - Usk, Washington mill utilizes the following basic components: biological selector, sulfite aeration/cooling surge tank, reactor primary clarifier for high solids bearing wastewater streams, Carrousel reactor, secondary clarifiers, gravity sludge thickener, sludge blending and dewatering equipment.

A Carrousel reactor is a conventional oxidation ditch system using high efficiency surface aerators as the means of imparting oxygen to the water and inducing sufficient velocity (0.3 m/s) to channel flows to keep solids in suspension. An F:M of 0.18, gives a solids residence time (SRT) of 15 days to meet BOD and TSS standards, and also stabilizes the sludge to be wasted. A mixed liquor suspended solids (MLSS) of 3000 mg/L ensures stability and buffering capacity against possible shocks or changes in feed conditions.

Each of the two Carrousel basins consists of eight 9.75 m wide channels 4.72 m deep. Overall plan dimensions are 80.2 m wide by 103.6 m long. Construction is of concrete. Seven 200-HP slow speed, specially designed surface aerators are used in each channel in the tank. By changing the water level by up to 0.3 m the motor power used is varied, allowing a power turndown ratio of up to 60%. One to three of the seven aerators may be taken out of service for purposes of power savings, maintenance, or repair without interfering with secondary treatment plant operation. The remaining aerators will be capable of maintaining sufficient channel velocity to prevent significant settling of solids. Feed from the sulfite aeration/cooling tank is mixed with recycled sludge in a small "selector" chamber and then overflows into a turbulent aeration zone.

While the oxidation ditch is a proven and effective effluent treatment process, it has been omitted from the alternative technology trains discussed in this report since it does not differ sufficiently in performance from an activated sludge process to merit the time required for cost estimating for all the mills.

Anaerobic treatment

Anaerobic processes for treating municipal sewage and food industry wastewaters have a long history, but are little used in the pulp and paper industry. Anaerobic treatment has recently attracted considerable attention, because technological advances have reportedly solved some of the problems in treating pulping wastes, and because of heavy promotion by several active vendors who have emerged in the North American market.

By far the most widely used applications of anaerobic processes in effluent treatment have been digestion of the waste sludge from municipal sewage activated sludge treatment plants, where a well designed and operated system can reduce sludge volumes by over 50%, while simultaneously improving its dewaterability. The same process could be used for sludge from pulp and paper industry activated sludge systems, but we are not aware of any operating installations.

History

The first installation of an anaerobic treatment system in the pulp and paper industry was at Container Corporation's waste paper based boxboard plant at Wabash, Indiana, in 1979. An anaerobic lagoon was installed on an existing aerated stabilization basin to reduce the BOD load caused by a plant expansion, downstream. It was still operating satisfactorily at the time of writing (personal contact). Another early installation in the paper industry was at the Roermand corrugating medium mill in Holland, and this plant has been the basis for the BIOPAQ Lavalin systems sold in North America.

Research has been extensive. A recent check of the Institute of Paper Chemistry's PAPERCHEM database showed 858 references to anaerobic treatment, and 888 to aerobic treatment. This apparent interest contrasts with a low frequency of installation in the Canadian pulp and paper industry where there are approximately 40 aerobic secondary treatment systems, mostly complying with permit conditions, and only three full scale anaerobic treatment systems running, of which only one was completely operational in mid 1990. In the US, there are roughly 500 aerobic secondary treatment systems in the pulp and paper industry, and only about five anaerobic systems.

Although considerable research interest exist in anaerobic treatment of pulp and paper mill effluents few full-scale mill installations exist. Almost all of the success stories in the industry deal with boxboard (linerboard) mills where a simple low rate anaerobic pond type system exists. The most notable examples are the Inland Container mills at Newport, Indiana and New Johnsonville, Tennessee (Strobel 1991). A similar installation exists at the Sonoco Products Co., Hartsville, SC mill.

The anaerobic treatment system in the pulp and paper mill at the Sonoco mill at Hartsville, SC, has been described by Winslow (1989). The installation suffers a 6 deg C drop in South Carolina winters, and slightly less in the summer. The temperature drop could be serious in Canada, but this would depend on location and raw effluent temperature. The reactor is an earthen basin with a flexible polyethylene uninsulated cover.

The major vendors of anaerobic treatment technology offer high rate systems, including the three described below. Low rate systems have been designed by consultants and mill engineers, and we are not aware of any vendors of proprietary systems. Not surprisingly, there is no commercial promotion of the low rate systems, despite their apparent success in a few locations.

In the chemical pulping industry few full-scale anaerobic treatment installations exist, many of which have been less than successful. For example, the anaerobic reactor commissioned during 1989 at the Alaska Pulp Corporation, Sitka, Alaska mill is reportedly still experiencing unsettled operation even though an intensive one-year pilot investigation preceded construction (Oetken 1990).

Even in the relatively few mills where non-sulphur pulping processes are used, there will be sufficient quantities of hydrogen sulphide in the gas for it to be lethal, either always or occasionally, so suitable safety precautions have to be taken in design and operation. While the necessary technology is well known, the cost is not insignificant.

At Alaska Pulp Corporation high levels of dangerous H_2S were found during start up above the lamella surfaces and this problem has continued to plague operations and creates a safety problem. Unfortunately pilot plant data on recovery time required after shutdown or upset, which has been shown to be exorbitantly long, appears to have been confirmed by full-scale operation.

Anaerobic treatment at Sturgeon Falls

The MacMillan Bloedel mill at Sturgeon Falls installed an anaerobic effluent treatment system in 1989/90 at a capital cost of approximately $12 million. The plant was commissioned in summer 1990, so that any conclusions on performance and operating costs must be considered as tentative. Annual operating costs are not yet established, but in November 1990 mill management advised that then current information indicated that they would be approximately $1.4 million. Maximum BOD load is approximately 30 tonnes/day, with removal efficiency about 70%, so that the plant can remove approximately 21 tonnes/day BOD.

The direct operating costs would appear to be approximately slightly under $200/tonne BOD removed. The capital cost is approximately $0.4 million/tonne BOD applied. We estimated capital costs from one to two million dollars per daily tonne BOD input, and operating costs from $250 to $500 per tonne BOD removed for conventional activated sludge plants and for the larger newsprint mills in Ontario. The costs of the Sturgeon Falls system appear to be competitive, assuming that the foregoing preliminary data reflect the actual costs that will become evident after one or two years operation, and that the plant performance proves to be reliable. However, if the mill has to install an aerobic system in series, the total cost of anaerobic and aerobic may exceed that of a single, larger aerobic system.

Anaerobic treatment does not have the potential to reduce effluent BOD, or raise the LC_{50} of pulp mill effluents to the levels normally required by most Canadian regulations, so it must always be followed by an aerobic system. Although toxicity reduction is absent or minimal, it appears that the anaerobically treated effluent is very amenable to aerobic treatment. Operators of the low rate anaerobic systems have reported very low suspended solids concentration, 30 mg/L, in subsequent aerated stabilization basins (Winslow 1989).

After many years of research, several groups consider that they have solved the technical problems of operating anaerobic treatment systems for pulp industry wastes. It is noticeable that the number of research/pilot plant publications on the subject has dropped off sharply in the past year or so, while a number of full scale systems are now in extended start-up phases.

In view of the number of Ontario mills that will probably have to install effluent treatment systems in the early 1990's, it is fortunate that this full scale experience is becoming available, and companies considering anaerobic treatment should take advantage of it by visiting operating systems.

Despite the obvious theoretical advantages of anaerobic processes over aerobic for treatment of the higher concentration pulp mill wastes, careful consideration of the probability of attaining reliable operation with the desired effluent quality is required. The number of installations operating by the early 1990's will lead to practical data becoming available.

We are not optimistic about the long term suitability of anaerobic treatment for non-kraft mill effluents in Ontario, and have not used anaerobic technology for estimating costs of compliance with the various potential levels of end-of-pipe effluent quality. Hopefully, experience in the next few years will prove us wrong, because the reduction in sludge disposal problems and energy consumption relative to aerobic effluent treatment, would be welcome if the anaerobic systems prove to be economic and reliable.

Several vendors offer turnkey or pseudo-turnkey high rate anaerobic systems. The vendors provide specialized hardware for the reactor's internal parts, design services, process know-how, and sometimes a guarantee of performance. It is important for engineers responsible for selection, or regulatory approval, of effluent treatments systems to realize that guarantees of process performance are extremely difficult to enforce in court. This is true regardless of the effluent treatment process involved, so that in practice the value of a guarantee depends more on the goodwill, reputation, ethical standards and financial strength of the vendor than on the legal wording. This is a difficult lesson that is currently being learned by at least one North American pulp and paper mill.

In comparison with the major equipment vendors whom the pulp and paper industry traditionally relies on for boilers, continuous digesters, paper machines, etc., and who include considerable process know-how in their packages, the supply infrastructure for anaerobic treatment systems is relatively immature.

Excepting for linerboard/boxboard mills where simple anaerobic systems are installed it does not appear that anaerobic treatment is a viable alternative to proven aerobic biological treatment in the North American pulp and paper industry. For this reason a detailed explanation of anaerobic treatment technology and experience is not presented in this report.

Complexity of process control

Anaerobic treatment systems require careful attention, and thereby require suitable instrumentation and laboratory facilities, as well as one or more staff members with the technical knowledge to interpret the data generated. Operation of such systems is not yet an exact science, and in many cases is closer to an ongoing research project that a routine industrial operation, so it is essential to have full time technical support staff, as well as adequate operating and maintenance personnel. To maintain high quality effluent, we consider that one full time professional with an engineering degree or similar qualifications is required, plus one or two technicians for testing. At least one full time shift operator is required, and perhaps more if the plant is not well designed for minimum operator labour.

Risk of mill shutdown

Historically, the regulatory authorities in Ontario and other parts of Canada have been quite tolerant of situations where mills have installed effluent treatment systems, and operated them well, but had an accident that reduced the treatment efficiency for a period. By demonstrating that every effort was being made to rectify the situation, mills were generally allowed to continue to operate. However, with the increasing public clamor for high quality water and enforcement of regulations, the danger of mills having to halt production during an upset in a waste treatment system is rising, and will presumably be greater where a mill discharges to a sensitive receiving water.

Membrane Technologies

Membrane filtration includes a broad range of separation processes from filtration and ultrafiltration to reverse osmosis. Generally filtration refers to systems having discrete holes or pores in filter media, generally in the order of 10^2 to 10^4 nanometre (nm) or larger. Efficiency depends entirely on the difference in size between the pore and the particle to be removed. Filtration processes relative to molecular size are identified in Table G.1.

Table G.1 Membrane processes

Material to be removed	Approximate size, nm	Process
Ion removal	1-20	Diffusion or reverse osmosis
Removal of organics in true solution	5-200	Diffusion
Removal of organics: subcolloidal-not in true molecular dispersion	200-10,000	Pore flow
Removal of colloidal and particulate matter	75,000	Pore flow

Reverse osmosis employs a semipermeable membrane and a pressure differential to drive fresh water to one side of the cell, concentrating salts on the input or rejection side of the cell. Here, freshwater is literally squeezed out of the feedwater solution (Eckenfelder 1989).

The criteria of membrane performance are the degree of impermeability, how well the membrane rejects the flow of the solute and the degree of permeability, or how easily the solvent is allowed to flow through the membrane. Because of the propensity of suspended or precipitated materials settling out on the membrane surface and plugging the membrane pores, turbulent flow conditions must be maintained (Reynolds numbers in excess of 2000).

Membrane life can be drastically shortened by undesired constituents in the feed water, such as phenols, bacteria, and fungi as well as high temperatures and high or low pH values. Generally, membranes will last up to two years with some loss in flux efficiency.

The present development of membranes limits their direct application to treating effluents having a total dissolved solids (TDS) not exceeding 10,000 mg/L. Further, the presence of scale-forming constituents such as calcium carbonate, calcium sulfate, oxides and hydroxides of iron, manganese, and silicon, barium and strontium sulfates, zinc sulfide, and calcium phosphate must be controlled by pretreatment or they will require subsequent removal from the membrane. This will be discussed further below. These constituents can be controlled by pH adjustment, chemical removal, precipitation, inhibition, and filtration. Organic debris and bacteria can be controlled by filtration, carbon, pretreatment, and chlorination. Oil and grease must also be removed to prevent coating and fouling of the membranes.

A summary of the operational parameters is presented in Table G.2.

Table G.2 Summary of system operational parameters

Parameter	Range	Typical
Pressure, kPa gage	2800-7200	4300
Temperature deg C	15-40	20
Packing density, m^2/m^3	150-1500	--
Flux, m/d	0.0035-0.030	0.005-0.03
Recovery factor, %	75-95	80
Rejection factor, %	85-99.5	95
Membrane life, years	--	2
pH	3-8	4.5-5.5
Turbidity, JTU	--	1
Feedwater velocity, m/s	0.01-0.75	--
Power utilization, kwh/m^3	2-4.5	--

Pulp mill effluents have been treated by reverse osmosis at a pressure of 600 psi. Wastewater were concentrated up to 100,000 mg/L total solids (Okey 1970).

Research using membrane technology to treat pulp and paper industry effluents began seriously during the 1960's with the Sulfite Pulp Manufacturers Association, Appleton, Wisconsin. The high energy utilization and short equipment and material life made these applications impractical for nearly all industry applications. A key illustration of the impracticability of the problem is shown in Figure G.1 which illustrates a proposed effluent treatment plant for a North American pulp mill. This figure shows that a complete physical-chemical-biological effluent treatment system is required for pretreatment prior to the membrane treatment technology.

The writer believes that, without exception, biological processes are more practical than membrane technology for environmental control in the pulp and paper industry. Incineration will not require the high cost pretreatment identified in Figure G.1.

Despite the low chance of success persistent research efforts continue with membrane technology. The Chinese report (Wagner 1989) installation of an ultrafiltration (UF) and a reverse osmosis (RO) plant at the Chinese pulp mill Kai Shan Tun in the Jilin Province that has been able to meet two objectives: 1. recovery of lignosulphonate and 2. reducing the COD discharge to a river. The membrane filtration plants were commissioned May 1987 and have reportedly been in steady operation since that time, treating more than 350 litres/minute of SSL. Installation of the membrane filtration plants has reduced the outlet of solids by 13,000 tonnes per year. Formerly these solids were dumped into a river.

There are three main products from the filtration plants:

> Sodium based lignosulphonate (LS) of high purity, up to 90%. The Na-LS is used domestically as a dispersant, e.g. for dyes, and it is also sold on the world market
> The permeate from the UF plant, which after concentration and drying can be used as a binder for fodder, due to the high sugar content
> RO permeate which is reused in the plant.

A number of closed cycle technologies such as ultrafiltration, polymer treatment, resin treatment, and activated carbon treatment would produce concentrated effluent streams by this technology that contain high concentrations of lignin, inorganic chlorides, and chlorinated organics. These streams would have to be treated either through recycling within the process or in a separate treatment system (i.e. a biological treatment step).

The Institute of Paper Science and Technology in Atlanta, which during the 1960's took over the Sulfite Pulp Manufactures Association research into membrane technology, continues 30 years later to research this technology in an effort to achieve closed cycle technologies at existing bleached kraft mills.

The authors believe membrane technology is not in the forefront for achieving the most practical solutions to in-plant environment controls in the pulp and paper industry. Numerous successful technical advances of in-plant controls, including within the bleach plant, have been realized within recent years. During the ten year period of 1978 to 88 water use and effluent flows for the US industry as a whole were reduced 30%. At the same time BOD/TSS loads were reduced 10%. Final effluent BOD discharges per unit of production during the decade are today one-third to one-quarter the amount and less than 5% that of 1943. Progress is continuing (Minor 1991). In Ontario's kraft mills, the reductions of BOD and TSS by measures to reduce discharges at source have been greater. as demonstrated by examination of the data presented by Bonsor (1988, pp 100-102) which shows that mills which did not have biological treatment in 1988 had reduced BOD by up to 50% over the preceding 20 years. Mills which added biological treatment had of course achieved more substantial reductions.

Most, if not all, membrane technologies for BOD, AOX, TOCl or toxicant removals incorporate within themselves a biological step (Erik 1991). The in-plant control steps are almost always unproven and in some cases the decisions to install membrane systems were based more on the availability of subsidies than technical analysis. The results are often unworkable solutions with high total cost. Unfortunately many of the membrane technologies are being developed by university researchers or equipment manufacturers who typically do not have a clear understanding of industry application requirements or what already exists in the marketplace.

Membrane concepts were commercially developed more than 30 years ago. Their fundamentals remain largely unchanged today. The industry has previously constructed and discarded full-scale membrane systems. No large scale successful industry applications exist in the North American pulp and paper industry today. We believe today's environmental engineering efforts could best be spent directed toward environmental engineering development efforts that do not incorporate membrane technologies.

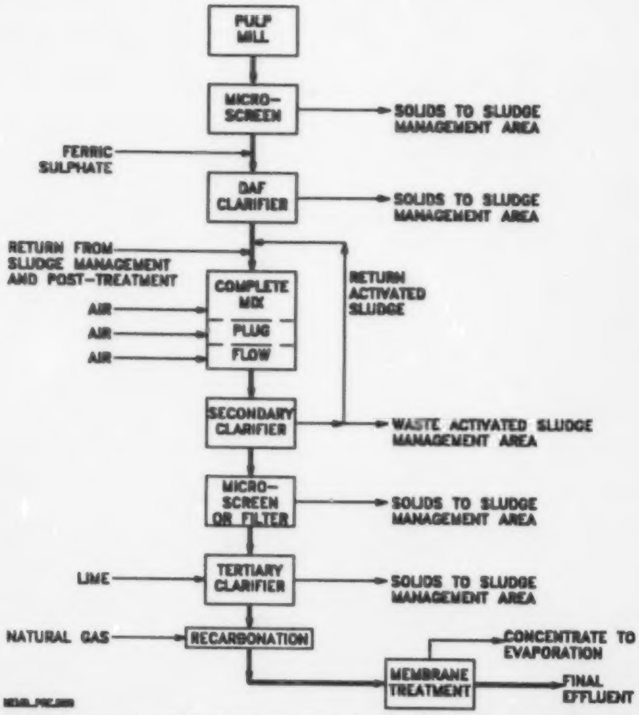
PULP MILL
MICRO-SCREEN
SOLIDS TO SLUDGE MANAGEMENT AREA
FERRIC SULPHATE
DAF CLARIFIER
SOLIDS TO SLUDGE MANAGEMENT AREA
RETURN FROM SLUDGE MANAGEMENT AND POST-TREATMENT
RETURN ACTIVATED SLUDGE
COMPLETE MIX
AIR
PLUG
AIR
FLOW
AIR
SECONDARY CLARIFIER
WASTE ACTIVATED SLUDGE MANAGEMENT AREA
MICRO-SCREEN OR FILTER
SOLIDS TO SLUDGE MANAGEMENT AREA
LIME
TERTIARY CLARIFIER
SOLIDS TO SLUDGE MANAGEMENT AREA
NATURAL GAS
RECARBONATION
CONCENTRATE TO EVAPORATION
MEMBRANE TREATMENT
FINAL EFFLUENT

Figure G.1 Proposed pretreatment processes prior to membrane treatment

(Figure presented to display the complexity of potential membrane systems for whole mill effluent)

One of the more recent, and relatively successful, installations of membrane technology is at the Husum bleached kraft mill in Sweden. Caustic extract from the bleach plant is filtered and the concentrate burned in the mill's recovery boiler. The objective is to remove the larger molecules which are relatively rich in organochlorines. The principal problem has been life of the membranes which was initially very short. Personal contact with engineers at the June 1991 SPCI conference in Stockholm indicated that membrane life was now expected to be about one year, although they did not yet have demonstrated experience of this. This system does not represent "pollution reduction at source", but rather it is an effluent treatment system that is most conveniently installed in the mill buildings, close to the bleach plant.

Appendix H

Terms of Reference

The terms of reference for this project are reproduced on the following pages. The report was prepared under two contracts, one for the kraft mills in Ontario and the other for the non-kraft mills. This single, integrated report was produced to take advantage of the overlaps in technology, thus reducing the overall cost.

ONTARIO MINISTRY OF THE ENVIRONMENT
REQUEST FOR PROPOSAL
MISA INDUSTRIAL PULP AND PAPER SECTOR

TITLE: **BEST AVAILABLE TECHNOLOGY (BAT) FOR POLLUTION CONTROL IN ONTARIO NON-KRAFT PULP AND PAPER MILLS**

OBJECTIVES:

INVENTORY OF BAT NON-KRAFT PULP AND PAPER MILLS

1.1 To develop an inventory of Best Available Technology (BAT) for pollution control that is presently being used in the non-kraft pulp and paper industry. The inventory should include, but not be limited to, design, operating and performance information and budget grade estimates of capital and operating costs. Best Available Technology includes in-plant controls and best management practices.

The present Ontario Ministry of the Environment definition of the term "Best Available Technology" is provided in Attachment I to this Request for Proposal.

INVENTORY OF GENERIC POLLUTION CONTROL TECHNOLOGIES

1.2 To develop an inventory of generic pollution control technology that is applicable to the non-kraft pulp and paper industry. The inventory should include, but not be limited to, design, operating and performance information and budget grade estimates of capital and operating costs.

IDENTIFICATION OF BAT TECHNOLOGY TRAIN OPTIONS

1.3 To evaluate and recommend, where possible, for each MISA non-kraft mill subcategory, five technology train options for Best Available Technology (BAT) for pollution control that are applicable to the mills in that subcategory. The MISA non-kraft mill subcategories are sulphite-mechanical, corrugating and deinking-board-fine papers-tissue.

EVALUATION OF ONTARIO NON-KRAFT MILLS WITH RESPECT TO BAT

1.4 To develop an inventory of the current effluent treatment technologies and in-plant controls at each of the Ontario non-kraft pulp and paper mills.

1.5 To compare the current status of each Ontario non-kraft pulp and paper mill to each BAT technology train option identified as applicable to that mill in 1.3.

1.6 To estimate, for each Ontario non-kraft mill, the expected performance, including performance variability, of applying each BAT technology train option identified for that mill.

ESTIMATION OF COSTS FOR ONTARIO NON-KRAFT MILLS TO ACHIEVE BAT

1.7 To provide budget grade estimates of the capital and operating costs for each Ontario non-kraft pulp and paper mill to adopt each of the applicable BAT technology train options.

BACKGROUND:

The Municipal/Industrial Strategy for Abatement (MISA) program is aimed at reducing discharges of toxic contaminants to Ontario's waterways. The ultimate goal of the MISA program is the virtual elimination of persistent toxic contaminants from all discharges to Ontario's receiving waters.

The MISA program for the Pulp and Paper Sector consists of a one year Effluent Monitoring Regulation which will be followed by an Effluent Limits Regulation. The Effluent Monitoring Regulation will end on December 31, 1990. Promulgation of the Effluent Limits Regulation is scheduled for June, 1992.

There are eighteen non-kraft pulp and paper mills in the province of Ontario that are regulated under the MISA program. These mills are divided into the sulphite-mechanical, corrugating and deinking-board-fine papers-tissue subcategories. The non-kraft mills are listed in Attachment II to this Request for Proposal.

FOCUS OF STUDY:

2.1 The study should focus on the environmental performance of non-kraft pulp and paper mills that are considered to be Best Available Technology mills.

2.2 The study should focus on the performance of demonstrated generic treatment technologies that are not currently used by, but that are applicable to, non-kraft pulp and paper mills. The generic treatment technologies may be linked in technology trains to provide BAT for each MISA non-kraft mill subcategory.

2.3 The study should focus on the identification of Best Available Technologies for effluent control including in-plant control and best management practices.

TASKS:

INVENTORY OF BAT NON-KRAFT PULP AND PAPER MILLS

3.1 Assemble information on the performance of non-kraft pulp and paper mills employing BAT components. The information should include:

1. Mill name and location.
2. Mill age/process technology age.
3. Manufacturing processes and design capacity.
4. Products and by-products.
5. Raw materials.
6. Rates of water use, reuse, and recycle.
7. Flow of wastewater per unit of production.
8. Technologies used for pollution reduction and control in the mill.
9. Effluent quality, including toxicity data (if available).
10. Effluent related regulatory requirements (mill permits).

3.2 The following information should be provided for each technology identified in 3.1.8:

1. Pollutants controlled and removal efficiencies.
2. Flow ranges in which the technology can be applied.
3. Range of raw wastewater quality with respect to parameters that the technology is designed to treat.
4. Effluent quality information with respect to the long term average concentrations and standard deviation that the technology can achieve for individual parameter removal.
5. Capital and operating costs of the technology.
6. Costs of waste disposal associated with the technology.
7. Energy requirements of the technology.
8. Comparison of the original design criteria to current operation and performance.
9. Limitations of the technology.

INVENTORY OF GENERIC POLLUTION CONTROL TECHNOLOGIES

4.1 Assemble information on generic treatment technologies that are not currently used by, but that are applicable to non-kraft pulp and paper mills. The Consultant will provide the information requested in 3.2.

IDENTIFICATION OF BAT TECHNOLOGY TRAIN OPTIONS

5.1 The Consultant will identify, where possible, five technology train options for each MISA non-kraft mill subcategory, that advance the Pulp and Paper Sector towards the MISA goal of the virtual elimination of toxics.

5.2 The Consultant will identify technology train options which minimize wastewater flows.

5.3 The Consultant will identify technology train options which produce effluent that passes the Ontario Ministry of the Environment acute toxicity tests for Rainbow Trout and Daphnia magna.

5.4 The Consultant will rank technology train options with respect to cost and overall environmental performance.

5.5 The Consultant will provide the information requested in 3.2 for each of the technology train options identified.

EVALUATION OF ONTARIO NON-KRAFT MILLS WITH RESPECT TO BAT

6.1 The Consultant will develop an inventory of the current effluent treatment technologies and in-plant controls at each of the Ontario non-kraft pulp and paper mills.

6.2 The Consultant will compare the current status of each Ontario non-kraft pulp and paper mill to the BAT technology train options identified as applicable to that mill.

6.3 The Consultant will estimate, for each Ontario non-kraft mill, the expected performance, including performance variability, of applying each BAT technology train option identified for that mill. This will include an estimate of the loadings of toxic contaminants, conventional parameters and non-conventional parameters that will be expected in the wastewaters generated from the use of the BAT technology train option.

ESTIMATION OF COSTS FOR ONTARIO NON-KRAFT MILLS TO ACHIEVE BAT

7.1 The Consultant will provide budget grade estimates of the capital and operating costs for each Ontario non-kraft pulp and paper mill to adopt each of the BAT technology train options identified for that mill.

REPORTING REQUIREMENTS:

8.1 On a monthly basis, for the duration of the contract, the Consultant will meet with the Ministry Project Liaison Officer and the MISA Pulp and Paper Sector BAT Subcommittee and will summarize all activities and findings from the previous month and planned future activities.

8.2 The Consultant will prepare a draft report on the findings of the above tasks. To the greatest extent possible, the report should include all raw data from which conclusions have been made.

8.3 The Consultant will prepare a final report after review and comment by the Project Liaison Officer and the MISA Pulp and Paper Sector BAT Subcommittee.

The date by which the draft report must be submitted is May 31, 1991 and the final report must be submitted one month later.

PROPOSAL REQUIREMENTS:

9.1 Formal proposals are being requested from all interested consultants in order to facilitate the selection process. The proposal should provide details of the following:

1. Understanding of the project and services to be provided.
2. Curriculum vitae of designated experts assigned to the project team.
3. Corporate qualifications and previous relevant experience.
4. Per diem rates for all staff on the project team.
5. Estimated cost, time and staff to perform each task, based on the Consultant's knowledge of the extent of work required.
6. Estimated expenses by expense category.

ONTARIO MINISTRY OF THE ENVIRONMENT
REQUEST FOR PROPOSAL
MISA INDUSTRIAL PULP AND PAPER SECTOR

TITLE: **BEST AVAILABLE TECHNOLOGY (BAT) FOR POLLUTION CONTROL IN ONTARIO KRAFT PULP AND PAPER MILLS**

OBJECTIVES:

INVENTORY OF BAT KRAFT PULP AND PAPER MILLS

1.1 To develop an inventory of Best Available Technology (BAT) for pollution control that is presently being used in the kraft pulp and paper industry. The inventory should include, but not be limited to, design, operating and performance information and budget grade estimates of capital and operating costs. Best Available Technology includes in-plant controls and best management practices.

The present Ontario Ministry of the Environment definition of the term "Best Available Technolgy" is provided in Attachment I to this Request for Proposal.

INVENTORY OF GENERIC POLLUTION CONTROL TECHNOLOGIES

1.2 To develop an inventory of generic pollution control technology that is applicable to the kraft pulp and paper industry. The inventory should include, but not be limited to, design, operating and performance information and budget grade estimates of capital and operating costs.

IDENTIFICATION OF BAT TECHNOLOGY TRAIN OPTIONS

1.3 To evaluate and recommend, where possible, five technology train options for Best Available Technology (BAT) for pollution control that are applicable to the Ontario kraft mills.

EVALUATION OF ONTARIO KRAFT MILLS WITH RESPECT TO BAT

1.4 To develop an inventory of the current effluent treatment technologies and in-plant controls at each of the Ontario kraft pulp and paper mills.

1.5 To compare the current status of each Ontario kraft pulp and paper mill to the BAT technology train options identified in 1.3.

1.6 To estimate the expected performance, including performance variability, of the BAT technology train options as applied to each of the Ontario kraft pulp and paper mills.

ESTIMATION OF COSTS FOR ONTARIO KRAFT MILLS TO ACHIEVE BAT

1.7 To provide budget grade estimates of the capital and operating costs for each Ontario kraft pulp and paper mill to adopt each of the BAT technology train options identified in 1.3.

BACKGROUND:

The Municipal/Industrial Strategy for Abatement (MISA) program is aimed at reducing discharges of toxic contaminants to Ontario's waterways. The ultimate goal of the MISA program is the virtual elimination of persistent toxic contaminants from all discharges to Ontario's receiving waters.

The MISA program for the Pulp and Paper Sector consists of a one year Effluent Monitoring Regulation which will be followed by an Effluent Limits Regulation. The Effluent Monitoring Regulation will end on December 31, 1990. Promulgation of the Effluent Limits Regulation is scheduled for June, 1992.

There are nine kraft pulp and paper mills in the province of Ontario that are regulated under the MISA program. These mills are listed in Attachment II to this Request for Proposal.

FOCUS OF STUDY:

2.1 The study should focus on the environmental performance of kraft pulp and paper mills that are considered to be Best Available Technology mills.

2.2 The study should focus on the performance of demonstrated generic treatment technologies that are not currently used by, but that are applicable to, kraft pulp and paper mills. The generic treatment technologies may be linked in technology trains to provide BAT for the MISA Pulp and Paper Sector Sulphate (kraft) Subcategory.

2.3 The study should focus on the identification of Best Available Technologies for effluent control including in-plant control and best management practices.

2.4 The study should focus on the identification of Best Available Technologies that will reduce or eliminate the discharge of organochlorines including chlorinated dioxins and furans. Alternative bleaching technologies that do not use chlorine or chlorine compounds for bleaching should also be investigated.

TASKS:

INVENTORY OF BAT KRAFT PULP AND PAPER MILLS

3.1 Assemble information on the performance of kraft pulp and paper mills employing BAT components. The information should include:

1. Mill name and location.
2. Mill age/process technology age.
3. Manufacturing processes and design capacity.
4. Products and by-products.
5. Raw materials.
6. Rates of water use, reuse, and recycle.
7. Flow of wastewater per unit of production.
8. Technologies used for pollution reduction and control in the mill.
9. Effluent quality, including toxicity data (if available).
10. Effluent related regulatory requirements (mill permits).

3.2 The following information should be provided for each technology identified in 3.1.8:

1. Pollutants controlled and removal efficiencies.
2. Flow ranges in which the technology can be applied.
3. Range of raw wastewater quality with respect to parameters that the technology is designed to treat.
4. Effluent quality information with respect to the long term average concentrations and standard deviation that the technology can achieve for individual parameter removal.
5. Capital and operating costs of the technology.
6. Costs of waste disposal associated with the technology.
7. Energy requirements of the technology.
8. Comparison of the original design criteria to current operation and performance.
9. Limitations of the technology.

INVENTORY OF GENERIC POLLUTION CONTROL TECHNOLOGIES

4.1 Assemble information on generic treatment technologies that are not currently used by, but that are applicable to kraft pulp and paper mills. The Consultant will provide the information requested in 3.2.

IDENTIFICATION OF BAT TECHNOLOGY TRAIN OPTIONS

5.1 The Consultant will identify, where possible, five technology train options that advance the Pulp and Paper Sector towards the MISA goal of the virtual elimination of toxics.

5.2 The Consultant will identify technology train options which minimize wastewater flows.

5.3 The Consultant will identify technology train options which produce effluent that passes the Ontario Ministry of the Environment acute toxicity tests for Rainbow Trout and Daphnia magna.

5.4 The Consultant will rank technology train options with respect to cost and overall environmental performance.

5.5 The Consultant will provide the information requested in 3.2 for each of the technology train options identified.

EVALUATION OF ONTARIO KRAFT MILLS WITH RESPECT TO BAT

6.1 The Consultant will develop an inventory of the current effluent treatment technologies and in-plant controls at each of the Ontario kraft pulp and paper mills.

6.2 The Consultant will compare the current status of each Ontario kraft pulp and paper mill to the BAT technology train options identified.

6.3 The Consultant will estimate the expected performance, including performance variability, of the BAT technology train options as applied to each of the Ontario kraft pulp and paper mills. This will include an estimate of the loadings of toxic contaminants, conventional parameters and non-conventional parameters that will be expected in the wastewaters generated from the use of each BAT technology train option at each Ontario kraft pulp and paper mill.

ESTIMATION OF COSTS FOR ONTARIO KRAFT MILLS TO ACHIEVE BAT

7.1 The Consultant will provide budget grade estimates of the capital and operating costs for each Ontario kraft pulp and paper mill to adopt each of the BAT technology train options identified.

REPORTING REQUIREMENTS:

8.1 On a monthly basis, for the duration of the contract, the Consultant will meet with the Ministry Project Liaison Officer and the MISA Pulp and Paper Sector BAT Subcommittee and will summarize all activities and findings from the previous month and planned future activities.

8.2 The Consultant will prepare a draft report on the findings of the above tasks. To the greatest extent possible, the report should include all raw data from which conclusions have been made.

8.3 The Consultant will prepare a final report after review and comment by the Project Liaison Officer and the MISA Pulp and Paper Sector BAT Subcommittee.

The date by which the draft report must be submitted is May 31, 1991 and the final report must be submitted one month later.

PROPOSAL REQUIREMENTS:

9.1 Formal proposals are being requested from all interested consultants in order to facilitate the selection process. The proposal should provide details of the following:

1. Understanding of the project and services to be provided.
2. Curriculum vitae of designated experts assigned to the project team.
3. Corporate qualifications and previous relevant experience.
4. Per diem rates for all staff on the project team.
5. Estimated cost, time and staff to perform each task, based on the Consultant's knowledge of the extent of work required.
6. Estimated expenses by expense category.

Glossary

This glossary is intended to assist readers unfamiliar with the technical terminology in the report. Many terms are standard in the fields of pulp and paper technology or environmental science, and are presented here for the readers convenience. Readers are recommended to refer to Smook (1990) for a more complete glossary of pulp and paper industry terminology.

Some terminology is not at all standardised. The authors have attempted to define all such terms used in the report in this glossary, in the context of their use herein.

2,3,7,8-TCDD	Tetrachlorodibenzo-p-dioxin.
2,3,7,8-TCDF	Tetrachlorodibenzofuran.
Activated sludge process	Biological treatment where micro-organisms are decanted after the principal reaction vessel and recycled to the effluent stream. Also known as "Activated Sludge Treatment" or "Waste Activated Sludge Treatment".
Active chlorine multiple	In a mixture containing molecular chlorine and chlorine dioxide. This quantiity represents the oxidizing power of the molecular chlorine and chlorine dioxide expressed as molecular chlorine equivalents. The active chlorine multiple is calculated as follows: $\frac{(Cl_2 + ClO_2 * 2.63)\% \text{ on o.d. pulp}}{\text{Kappa number of the unbleached pulp.}}$
Acute	With reference to toxicity, happening quickly, usually within 4 to 7 days for fish. Can describe an effect, or the duration of a test, e.g. an acute test. An acute effect could be a mild or sublethal one.
ADI	Acceptable Daily Intake. The amount of a substance that is considered "safe" to take into the body, on a daily basis, for a lifetime. This is almost always for humans. The value of ADI is decided by a regulatory body, after considering relevant scientific data.
Aerated stabilization basin	Biological treatment process characterized by absence of sludge recycle and by a long hydraulic retention time (typically several days).
Aerobic treatment	Refers to biological processes tc treat effluents, in which the principal reactions take place in the presence of dissolved oxygen.
Air dry	The term "Air dry" refers to pulp and signifies 90% dry fibre and 10% moisture (1 ADt = 900 kg OD pulp). The abbreviation t_{90} is frequently used in Scandanavia.
Anaerobic treatment	Refers to biological processes for effluent treatment in which the principal reactions take place in the absence of dissolved oxygen.

AOX	Adsorbable Organic Halogens. A measurement of the amount of chlorine attached to organic substances. The amount of AOX measured in a sample according to a German standard test (DIN 39-409) or similar tests. Chlorine is the only halogen used in significant quantities in pulp mills. The measurement is expressed as weight of the halogens (chlorine), not the weight of the entire organic molecule.
ASB	Refer to aerated stabilization basin.
AST	Activated Sludge Treatment. Synonymous with activated sludge pocesss.
Atomic Chlorine	refers to any form of chlorine, combined with other elements or molecular *(qv)*
Atomic chlorine multiple	In a mixture containing molecular chlorine and chlorine dioxide, this quantity represents the total chlorine present in the system. Atomic chlorine refers to any form of chlorine, that is, molecular chlorine and chlorine combined with other elements; eg. ClO_2, NaOCl, etc.combined or molecular. The atomic chlorine multiple is calculated as follows: $\dfrac{(Cl_2 + ClO_2 * 2.63/5)\text{\% on o.d. pulp}}{\text{Kappa number of the unbleached pulp.}}$
AVG_{30}	30 day rolling average performance of a treatment plant: $AVG_{30} = \dfrac{\sum_{i=1}^{n} x_i}{n}$ where n= number of data points in that 30 day period. The term is used to evaluate the performance of a treatment plant. Outliers are included in the measure, so that in the case of extreme outliers, the AVG_{30} may exceed the MAX_{95} which excludes outliers. Performance may refer to concentration, mass or other effluent characteristic measured on a 24 hour composite sample of mill effluent.
AVG_{95}	Annual 95th percentile of the distribution of daily performance of a treatment plant. Essentially the long term average discarding the top and bottom 2.5% of values. An approximate calculation has been used in this report: $AVG_{95} = \dfrac{\sum_{i = (0.025 * n)_{\text{o dec.}}}^{(0.975 * n)_{\text{o dec.}}} x_i}{n}$ where n= number of data points in that 30 day period.

	Performance may refer to concentration, mass or other effluent characteristic measured on a 24 hour composite sample of mill effluent.
BCTMP	Bleached Chemi-Thermomechanical Pulp.
Benthic	An adjective describing organisms that live on the bottom in a body of water, or non-living things that are on the bottom, or part of the bottom. Most often used for "benthic invertebrates". Benthos is a noun referring to the assemblage of organisms that live in, on or near the sediment or other substrate of a body of water.
Bioaccumulation	A general term, meaning that an organism stores within its body, a higher concentration of a substance than is found in the environment. This is not necessarily harmful. For example, freshwater fish must bioaccumulate common salt if they are to live. Many toxicants, such as arsenic, can be handled and excreted by aquatic organisms, so that they are not included among the dangerous bioaccumulative substances.
Bioassay	This term can be used for toxicity tests with fish, but it is probably best to reserve it for the formalist procedures used in testing the potency of drugs (pharmaceuticals).
BK, BKM, BKME.	Abbreviations for Bleached Kraft, Bleached Kraft Mill, and Bleached Kraft Mill Effluent. All refer to a pulp mill that operates by the kraft or sulphate process, and bleaches some or all of the product.
Black liquor	A liquid in the kraft process, composed of spent pulping chemicals and wood residues. Weak black liquor refers to concentrations under 20% solids, strong black liquor to concentrations over 50% solids.
Bleaching	In the context of this report, refers to raising the brightness of chemical pulps by selective chemical removal of residual lignin and other coloured materials. Refer also to "brightening". Most bleaching processes use chlorine compounds.
Blow tank	A tank which receives the pulp discharged (blown) from the digester in a chemical pulp mill
BOD	Biochemical Oxygen Demand is a property of water or wastewater, determined by measuring the quantity of oxygen consumed by a sample under controlled conditions (20 deg C, neutral pH) for a defined time period. The most commonly used period in North America is 5 days which is sometimes written as BOD5. BOD is expressed as mg/L ("parts per million"), the same unit as is customary for dissolved oxygen, or simply as a weight, as in "kg of BOD per tonne of pulp".
Bone dry(BD)	Outdated term for oven dry (qv).

Bound soda	In brown stock washing, soda that is retained in the pulp by physical/chemical forces, is referred to as bound soda. Mill control tests sometimes exclude bound soda in routine tests and account for it by a predetermined factor. Normally expressed as Na_2SO_4.
Brightening	Chemical modification of lignin and other coloured components of high yield pulps in the mechanical-sulphite spectrum to raise brightness. The coloured components are not removed, in contrast to bleaching processes (*qv*). Brightening processes do not use chlorine compounds.
Brightness	A measure of the whiteness of paper as compared to a standard.
Brown stock	Kraft slush pulp prior to bleaching. Unbleached pulp from an alkaline pulping process.
Carcinogenic	Capable of causing cancer.
Caustic	Commonly used name for sodium hydroxide.
Caustic extraction	Bleaching stage where highly coloured organics are dissolved with alkali, normally NaOH.
Causticiser	A tank used to allow calcium hydroxide and sodium carbonate to react and form sodium hydroxide and calcium carbonate.
Chemical pulp	Wood pulp which has been manufactured by chemically separating the fibres that make up solid wood. Kraft and sulphite are the most common examples. The term chemical contrasts with mechanical, (qv). Since the 1970's, a significant and increasing proportion of wood pulps have been hybrid mechanical/chemical.
Chlorine-compound-free	Pulp bleached without any chlorine compounds. In a traditional bleach plant this would imply elimination of use of chlorine, chlorinie dioxide and hypochlorite.
Chlorine dioxide substituton	Although an unprecise expression, this term generally refers to the practice of replacing the bleaching function of molecular chlorine with chlorine dioxide.
Chlorine equivalent	Refer to "Equivialent chlorine"
Chlorine free	Poorly defined term. Some users mean pulp which is bleached without the use of molecular chlorine, when it usually refers to pulp bleached with 100% chlorine dioxide substitution in the chlorination stage. Others mean chlorine-compound-free when using this term. Refer also to molecular chlorine.

Chronic	Long-lasting or continued. Can refer to the effect or the duration of exposure. In mammalian toxicology, usually signifies exposures lasting at least one-tenth of a lifetime. In aquatic toxicology, is sometimes used to mean a full life-cycle test.
CMP	Chemimechanical Pulping. Chips are pretreated with a chemical at an elevated temperature prior to atmospheric refining to produce a pulp yield over 80%.
COD	Chemical Oxygen Demand. A similar concept to BOD, except that the measurement is of oxygen consumed, based on rapid chemical oxidation of the sample. BOD and COD are generally poorly correlated.
Condensate	Water condensed from steam which has come into contact with a surface at a lower temperature during a process. Contaminated or foul condensate usually refers to a condensed vapor from evaporation of black liquor or other spent pulping liquor.
Coniferous trees	Cone-bearing and evergreen trees, such as spruce, hemlock, Douglas fir, pine.
Consistency	Weight per cent of moisture free, or air dry (as specified) fibres in a suspension of pulp fibres in water.
Conventional bleaching	Refers to the bleaching of kraft pulps obtained by conventional pulping to market brightness by the sequential use of the following stages: chlorine with no more than 10% substitution of molecular chlorine with chlorine dioxide; sodium hydroxide with or without oxygen; chlorine dioxide or sodium hypochlorite or both; sodium hydroxide; and chlorine dioxide.
Conventional pulping	Conventional pulping refers to the pulping of softwoods to obtain a bleachable grade of pulp with a lignin content measured as 30 Kappa number, plus or minus 5 units, using co-current continuous digesters or conventionally blown batch digesters.
Cook	Normal term in the pulp and paper industry for the chemical pulping process in the digester where the fibre is separated from lignin by chemicals under conditions of elevated temperature and pressure.
CTMP	Chemi-thermomechanical pulping. Similar to TMP. Chemical is added to the chips either prior to or during the presteaming of the chips with first-stage refining at an elevated temperature of over 100 deg C and any subsequent refining at atmospheric pressure. Retention time and pressure in the presteaming device is normally such that yields are in the 90% plus range.
DBD	Dibenzo-p-dioxin. A precursor present in certain raw materials, when chlorinated it can be converted to TCDD.

DBF	Dibenzo-p-furan. A precursor which is detectable in chips, unbleached pulp and raw material supplies or additives. When chlorinated it can be converted to TCDF.
Decanter (turpentine)	A tank used to separate turpentine from condensate.
Deciduous trees	Hardwoods or broadleaf trees which lose their leaves in winter, such as alder, maple, oak, birch, cottonwood.
Decker	An apparatus for dewatering pulp by filtering the fibres out on a mesh covered drum.
Defiber	Break wood down into separate fibres, usually by mechanical means, to make wood pulp.
Dilution factor	A measure of the efficiency in pulp washing when the pulp is well washed. Mathematically the dilution factor is the ratio of incoming water consumed to oven dry pulp washed.
Dissolved solids	Substances that are dissolved in the water, and will pass through the filter used in the standard method of measurement. They are measured by evaporating the water and weighing the solids that are left behind.
DO	Dissolved oxygen, normally measured in milligrams/litre and widely used as a criterion of receiving water quality.
EC50	Median effective concentration. As LC50, except that it may apply to any effect, lethal or non-lethal. The effect as well as the exposure-time must be specified.
Ecosystem	An interacting system of all living organisms in a circumscribed region of similar characteristics, and the non-living substrate, nutrients, energy, and other environmental components.
Effluent	A waste material discharged into the environment. In this report, the effluent refers to the liquid waste with its suspended and dissolved materials, which is discharged into surface waters.
Effluent standard	A regulation concerning the quality of a liquid waste, or the concentrations of substances that it may contain. This standard applies "at the end of the pipe".
Elemental chlorine	Refers to chlorine used to bleach pulp when applied as a component of some other compound, normally chlorine dioxide, hypochlorite (sodium or calcium), or chlorine monoxide. The authors have generally avoided this term in the report, using "Atomic Chlorine" *(qv)*.

EMPPL	Effluent monitoring priority pollutants list. A list of substances considered environmentally significant by the Ontario Ministry of the Environment. Very similar to the USEPA Priority Pollutants List.
EOX	Extractable organohalogens, using a non- or semipolar solvent such as hexane or ethylacetate for the extraction. Extractable chlorines (EOCl) or persistent, extractable organohalogenes are variations of the analytical procedure.
Equivalent chlorine	The term "chlorine equivalent" is widely used to define the "equivalent bleaching power" of the popular bleaching chemicals. It refers to a simple comparison of free electrons available to oxidize lignin in the bleaching reactions. Common values are: Chlorine = 1 Oxygen = 2 Hypochlorite = 2 Hydrogen Peroxide = 2 Chlorine Dioxide = 2.63 Ozone = 3 In practice, the actual values vary somewhat, but the above values are useful for rapid estimates. With the disappeance of chlorine from an increasing number of bleach plants, the term **"oxidizing equivalent"** is being used rather than "chlorine equivalent"
Exit	In the context of this study, refers to materials leaving a process, system or plant.
Extended cooking	A sub-set of extended delignification processes which are implemented in the digester.
Extended delignification	Refers to a variety of processes developed over the past twenty years to extend delignification of kraft pulps beyond the traditional levels of Kappa of about 30 for softwoods and 15 for hardwoods, without using chlorine compounds As used in this report, it would include extended cooking (*qv*), oxygen delignification, ozone delignification and any other delignification process prior to the bleach plant.
F:M ratio	Food to Microorganism ratio. Term used in biological effluent treatment to designate ratio of "food" (normally expressed as BOD) to biomass in a biological reactor
Fillers	Minerals, synthetic mineral-like material used to fill voids which occur between fibres. Many printing and writing papers contain substantial amounts of filler. Standard newsprint does not contain fillers.

Filter	A device used to separate suspended solids from a liquid or gaseous carrier.
Filtrate	The liquid that passes through a filter. In pulp processing, filtrate is usually white water.
Free soda	In brown stock washing, soda that can be washed from the pulp by a standard washing and filtering test. Free soda and bound soda constitute the total soda loss . Synonymous with washable soda.
Furnish	The specific mixture of raw materials, both pulp and chemicals, from which a particular grade of paper is manufactured, ready to be delivered to the paper machine.
Green liquor	A liquid in the kraft process composed of the chemicals obtained from the recovery furnace. Primarily sodium sulphide and sodium carbonate in aqueous solutions.
Grits	In kraft mills, the inert lime rejected from the slaker in the recausticising department, includes impurities such as sand and unconverted limerock or limemud.
Groundwood or GWD	Stone Groundwood. Commonly called groundwood pulp. Logs are torn into separate fibres by being forced into contact with a rotating grindstone. The axes of the log and stone are parallel. The oldest widely used pulping process. May also refer to Refiner Groundwood.
Hemicellulose	Portion of wood fibre consisting of sugar-like substances intimately associated with cellulose in the fibre wall and removed mainly in the cooking process.
Hog fuel	Term for wood waste fuel widely used in pulp and paper industry boilers. It includes some of the following: bark; sawdust; reject chips; sticks; branches; cutoffs; and other sawmill and wood harvesting wastes. A major component is usually bark.
HYS	High-yield Sulphite. Normally refers to sulphite pulping in the yield range of 55% to 80%.
In-plant	As used in this report refers to water pollution abatement measures which rely primarily on modifications to the production process or operating procedures. Examples include reuse of water, replacement of liquid ring vacuum pumps with dry pumps, replacement of open screens with closed screens to reduce accidental spills, improved process control and operator training.

K No.	Synonymous with Permanganate No. (*qv*).Permanganate No. A mill test that measures the degree of cooking, or delignification of kraft pulp. Although, it is related to lignin content, it does not have a linear relationship to it. For both high yield and low lignin content pulps, the Kappa number was developed to provide a linear measure of lignin over a wide test range.
Kappa Number	A measure of lignin in pulp, according to a standard laboratory procedure. Bleachable grades of unbleached kraft pulp generally have a Kappa number from 5 to 35, depending on the wood species and the extent of delignification. When extended delignification is practiced in a mill, the wide range of lignin content is more accurately reflected by the Kappa number than by the K number.
KM, KME	Kraft mill and kraft mill effluent. See BK.
Knotter	A type of screening device used to separate knots and other large, oversized and unwanted material from wood pulp.
Kraft pulp	Pulp produced by the kraft process. Also known as sulphate pulp.
LC_{50}	Median lethal concentration. The concentration of a substance that is estimated to kill half of a group of organisms. The duration of exposure must be specified (e.g. 96-hour LC_{50}).
Lethal	Causing death, or sufficient to cause death.
Machine dry	The degree of dryness of pulp, or more commonly paper, as it leaves the drying machine.
Machine finish (MF)	The normal finish applied to the paper when manufactured on a paper machine equipped with conventional dryers (differentiated from a Yankee dryer).
Market pulp	Pulp products such as bleached or chemical pulps or mechanical pulp sold to customers outside the producing company for machine furnish.
MAX_{95}	Annual maximum of the 95th percentile of daily performance of a treatment plant. Excludes the 5% most extreme values that reflect malfunctioning of the treatment plant or the mill. An approximate calculation has been used in this report: $MAX_{95} = x_{(i=0.95*n)}$ where n= number of data points in the period. Daily performance is better than MAX_{95} 95% of the time. Performance may refer to concentration, mass or other effluent characteristic measured on a 24 hour composite sample of mill effluent.

Maximium daily discharge	Highest value of concentration, mass or other effluent characteristic measured for one day on a 24 hour composite sample of mill effluent.
MBC	Modified Batch Cooking. Generally refers to modifications to batch cooking processes intended to reduce the Kappa number of the product while preserving or enhancing strength.
MCC	Modified Continuous Cooking. Generally refers to modifications to continuous cooking systems manufactured by the dominant technology vendor (Kamyr Inc), to reduce the Kappa number of the product while preserving or enhancing strength.
Mechanical pulp	Wood pulp which has been manufactured by physically tearing apart the fibres that make up solid wood. Groundwood, TMP and RMP are the most common examples. The term mechanical contrasts with chemical (qv). Since the 1970's, a significant and increasing proportion of wood pulps have been hybrid mechanical/chemical.
mg/L	Milligrams of the substance in question, contained in one litre of solution. Roughly speaking, parts per million. This is the common unit for assessing water quality.
MISA	Municipal/Industrial Strategy for Abatement. Ontario Ministry of the Environment program which has a principal goal of reducing the discharges of water pollutants, particularly toxic and or persistent substances.
ML(V)SS	Mixed liquor suspended solids. Term used in biological treatment referring to the concentration of suspended solids in the biological reactor. "V" refers to the Volatile fraction, and is used to indicate the concentration of organic matter.
Molecular chlorine	As applied to bleaching and substitution refers to industrially pure Cl_2, normally applied to the pulp in gaseous form. The term is used to distinguish this from chlorine used in the form of a compound such as chlorine dioxide or sodium hypochlorite.
Molecular chlorine free	Refers to pulp bleached without use of molecualr chlorine (chlorine compounds may be used).

Molecular chlorine multiple	In a mixture containing molecular chlorine and chlorine dioxide, the molecular chlorine multiple represents the chlorine present in its molecular form and is calculated as: [Cl_2, % on OD pulp]/Kappa number of the unbleached pulp. If no chlorine dioxide is mixed with the chlorine, then active, atomic and molecular chlorine multiples are all equivalent to one another.
Mutagen	A chemical that causes an alteration of the inherited genetic material, i.e. the DNA of the genes. In the narrow sense, the chemical alters the genetic material of paternal or maternal sex cells.
NCASI	The National Council for Air and Stream Improvement - a US environment research organization sponsored by the US pulp and paper industry.
NCG	Non-condensable gases are gases emitted from several parts of the kraft pulping process which do not condense in the commonly installed condensing equipment. TRS and/or methanol are the predominant components.
NOEC	The no-observed-effect concentration. The highest concentration in a sublethal test that does not cause a significant adverse effect, in comparison to the controls.
NOEL	No-observed-effect level. Similar to NOEC
Non-detectable	Refers to failure to detect a substance when analysing a sample. The minimum level of detection depends on many factors in addition to the characteristics of the substance itself, so the threshold of detection cannot be defined simply. In Ontario, the term "non-detectable" is defined with reference to the accepted detection limit for a defined analytical procedure. In some cases, (e.g. Environment Canada 1991 proposed regulations for dioxins) "non-detectable" refers to a defined, normally very low, concentration. The lower limits of detection of most pollutants are decreasing rapidly, due to extensive research, so that caution is required in interpreting the term "non-detectable"
NPOX	Non-purgeable organic halogen (See also AOX, POX)
NSPS	New Source Performance Standards. Term used by the US EPA and some states to refer to a set of effluent and atmospheric emission standards that new plants must comply with. Generally very stringent.
OD	Refer to oven dry.
Oligotrophic	The condition of a lake which has low productivity because of lack of nutrients. The water would be clear. Lake Superior is oligotrophic.

Organochlorine	Chlorine which is combined with organic molecules or bound to them. Many organochlorines are formed in bleaching processes whenever chlorine or chlorine based compounds are used. Thousands of chlorinated organic compounds exist, but only a small proportion of those in pulp mill effluents have been identified. AOX is one of many ways of measuring organochlorines, and it expresses the result the weight of organically bound chlorine, not the weight of chlorinated organic molecules.
Oven dry (OD)	Pulp or paper dried in an oven by a standard laboratory procedure to the point where it contains no moisture. The term Bone Dry (BD) is commonly used synonymously (this is now obsolete). When applied to market pulp, oven dry weight divided by 0.9 by definition of the pulp (see Air dry) equals the air dry weight.
Oxidation efficiency	(As applied to kraft black liquor) Percentage reduction of sodium sulphide concentration in the black liquor after it has been oxidized by blowing air or oxygen through the liquor, as applied to black liquor oxidation processes.
Oxidising equivalent	Refer to equivalent chlorine.
Particulate emissions	Generally, this consists of all solid material discharged from a stack or vent. Specifically the particulate flow is defined by a standard test method. Particulate emissions are usually expressed as mg/m3.
PGW	Pressurized stone groundwood. Similar to groundwood, except that the logs are ground under pressure at temperatures around 100 degrees C. This process was developed recently.
pH	A measure of the acid or alkaline nature of water or some other liquid. Specifically, pH is the negative logarithm of the hydrogen ion concentration (H_3O^+). Practically, pH 7 represents a neutral condition in which the acid hydrogen ions balance the alkaline hydroxide ions. Values of pH below 7 represent acid conditions and values above 7 are alkaline. A change of one unit, for example from 7 to 6, represents a ten-fold increase in hydrogen-ion activity, and thus a ten-fold increase in the "acidic" nature of a water. Soft northern waters would typically range from pH 6 to 7.5; hard waters of southern Ontario would usually be close to pH 8. The pH of the water can have an important influence on the toxicity of chemicals in effluents.
Pollution	With reference to water pollution, the addition of something to the water, resulting in a measurable effect, which is deleterious to some use of the water by living organisms including humans.
POX	Purgeable organic halogen (see also AOX, NPOX)

Precipitator (electrostatic)	A piece of equipment which uses electrostatic forces to recover solids from a gas stream by the use of high voltages applied to plates or wires in the stream.
Precursors	A group of unchlorinated dioxins/furans which have the potential to be transformed into chlorinated dioxins/furans during combustion or treatment with elemental chlorine such as in the pulp bleaching process.
Pretreatment	Describes initial treatment processes before an effluent reaches primary treatment. The processes are designed to remove grit, coarse material and debris, to neutralize acid or alkaline wastes, and to equalize the effluent characteristics and flows. This is carried out by mixing the collected effluent streams and directing occasional large flows or concentrated streams to spill tanks or basins. This is a normal part of pulp mill operations.
Primary treatment	This is intended to remove suspended solids from the effluent and normally includes dewatering the recovered settled solids or sludge to facilitate disposal to landfill or by combustion. Primary treatment is a prerequisite for most secondary treatment processes.
PRMP	Pressure refined mechanical pulp. Similar to PTMP except that the chips are not presteamed at an elevated temperature prior to refining which is customary for TMP and PTMP systems.
PTMP	Tandem or "pressure/pressure" thermomechanical pulping. Similar to TMP except that both primary and secondary stages of refining are pressurized. This approach is becoming so common in new installations that the term "TMP" may be used.
RDH	Rapid Displacement Heating. Process modification to improve heat economy and lower product Kappa number for batch pulping systems in kraft mills. This is a Beloit process.
Recovery furnace	A unit used to burn recovered cooking liquor to produce steam and to recover cooking chemicals. Frequently known as the recovery boiler.
Refiner	As applied to pulping wood, or modifying pulp fibres in paper making. A device which separates fibres by passing the wood chips through a narrow gap between rotating and stationary plates with serrated surfaces. Since the early 1970s, refiners have become the mainstay of most pulping processes except kraft.
Refiner groundwood	Mechanical pulp made by separating wood chips into discrete fibres in a refiner.
Residue filtered	(RSF) Term used in many MOE documents for dissolved solids.
Residue particulate	(RSP) Term used in many MOE documents for suspended solids (q.v.).

Retention aid	Generic group of chemicals used in small quantities to improve the retention of fine fibres and fillers on paper machine wires. Widely used in fine papers, they may be used in almost any type of paper mill.
Reversion	Tendency of a pulp or paper sheet to lose brightness with time. Typically several brightness points are involved, over time spans of days to months.
RMP	Refiner mechanical pulp. Atmospheric refining with no pretreatment.
Saveall	Equipment used to recover fibres and filler from the white water. Usually a wire-covered rotating drum or wire-covered discs. Vacuum is employed to draw the water through the wire. Today, the "wires" are usually plastic. There are several other types of save-alls working on a sedimentation or flotation principle.
Screen room	A common term for the screening and cleaning department which usually follows a pulping operation.
Scrubber	A piece of equipment used to remove certain gases or solids from a gas stream normally utilizing a spray of liquid, such as water or an aqueous solution of reactant. Dry scrubbers are used for some applications.
Secondary treatment	A stage of waste treatment in which micro-organisms decompose organic constituents in the effluent. In the process, they use oxygen for their metabolism and to oxidize the waste material. Most secondary treatment processes also reduce toxicity.
Shives	A small bundle of fibres that has not been separated completely in the pulping operation.
Shrinkage	A term normally applied to the pulp loss in bleaching due to removal of lignin. Usually expressed as percent. Pulp typically shrinks about 7% on bleaching. It also refers to losses in deinking.
Sludge filter	A piece of equipment used to concentrate suspended solids by removing water from them. The solids are recovered after settling in a clarifier.
Smelt	The inorganic chemicals that are obtained in molten form from the recovery furnace.
Soda loss	The loss of sodium salt due to imperfect washing of the pulp, or in the recovery of sodium compound in the chemical recovery system. For pulp washing the measure should include both bound and free soda, and for clarity reports should state what is included. The intent is to include all soda leaving with the pulp.

Stock	A general term for a suspension of pulp fibre in water; usually implies a consistency between 0.2% and 15%. A papermaker's terms for the beaten, refined and mixed materials (furnish) in a water suspension as supplied to the paper machine (also called "stuff").
Stock preparation	A term for the operation which occurs between pulping or bleaching and formation of the web on the paper machine. The operations may include blending of several pulps, addition of colour, filler and other materials and chemicals.
Sublethal	A concentration or level of a substance that would not directly cause death. An effect that is not directly lethal.
Sulphate pulp	A term that is often used for kraft pulp, especially in Scandinavian literature.
Sulphidity	In white liquor, the percentage of sodium sulphide to sodium sulphide plus sodium hydroxide, with all compounds expressed as sodium oxide.
Sulphite pulp	A chemical pulp which is manufactured by separating the fibres of wood chips by cooking (qv) them in a hot solution of sodium, magnesium, calcium or ammonium sulphite and sulphur dioxide under pressure.
Suspended solids	Particles of matter suspended in the water. Measured as the oven dry weight of the solids, in mg/L, that are retained on a standard filter paper. Less than 25 mg/L would be considered clean water, while an extremely muddy river might have about 200 mg/L of suspended solids. The term "Total Suspended Solids" (TSS) is now the correct term to use in North America, and it is rare to report suspended solids other than as Total Suspended Solids, although the suspended solids component of a wastewater can be broken down analytically into many subdivisions if desired. In Sweden the TSS analysis is carried out with 70 micron wire filter which is much more open than the APHA standard used in North America and results in lower TSS values.
t_{90}	Refers to air dry tonnes. Commonly used in Scandinavian literature, but little used in North America where the normal abbreviaiton is ADt.
TCDD/TCDF	In this report TCDD/TCDF refers to 2,3,7,8-TCDD and 2,3,7,8-TCDF.

TEF	Toxicity Emission Factor. A measure of the amount of toxicity discharged in an effluent. It is the toxicity of the effluent multiplied by the volume of effluent discharged for each tonne of production at the mill. The calculation is usually based on the lethal concentration of the effluent (LC50) to trout or other fish. Since toxicity is the reciprocal of LC50, TEF is equal to 100 times the number of cubic metres of effluent discharged per tonne of product, divided by the LC50 as a percentage. The numerical value of TEF may be thought to represent the number of m^3 of "just-barely-lethal" effluent that are discharged for each tonne of product. (TEF may also be obtained by dividing the TER by the daily production.)
TER	Toxicity Emission Rate. Similar to TEF, but a measure of the amount of toxicity discharged in an effluent during unit time, usually during one day. It equals the toxicity of the effluent multiplied by m^3 of effluent per day. TER is equal to 100 times the number of m^3 of effluent per day, divided by the LC50 as a percentage.
Tertiary treatment	This is a final process of effluent treatment after primary and secondary treatment steps. It embraces a broad range of processes used to remove items such as colour, odour, taste, and toxicity. It is often used for removing nutrients, especially phosphorus, from municipal effluents.
TMP	Thermomechanical pulp. Chips are steamed and refined at an elevated temperature in a "primary" refiner, normally followed by second-stage atmospheric refining.
TOCl	Total organically bound chlorine. Quantity of organically bound chlorine in a sample, determined according to a method described by Sjostrom (1982). This is similar to the measurement of AOX, except that the TOCl is sorbed onto XAD (ion-exchange resin), instead of activated carbon. This is a measure of the total chlorine in organic compounds, many of which may be unidentified. This term has been replaced by AOX in most countries.
TOX	Abbreviation commonly used to refer to the Total organic halogen analytical procedure defined by APHA et al (1989). This provides a measurement that is essentially the same as AOX.
Toxic	Generally, describes a substance, a dose, or a concentration that is harmful to a living organism by means of chemical action. **In the context of this report, "toxic" refers to acute lethality to rainbow trout (96-hour LC_{50}) or *daphnia magna* (48-hour LC_{50}), as determined by the Ministry's standard tests,** unless otherwise noted. It bears little or no relationship to the toxicity of an effluent to humans, toxic effects on algae, plants or bacteria, or the persistence or bioaccumulative properties of the substances.

Toxicity	The quality or action of being toxic. The action of causing severe biological damage.
Toxicity test	Any test in which the harmful action of a substance is measured by observing the effect it has on a living organism, organisms, or some living system.
TRMP	Thermo-refiner mechanical pulp. Chips are presteamed at a temperature over 100 deg C and then refined at atmospheric pressure.
TRS	Total reduced sulphur. A general term for sulphur gases emitted from the kraft process, excluding sulphur dioxide and trioxide. Generally considered to include hydrogen sulphide, dimethyl sulphide, dimethyl disulphide and methyl mercaptan. These gases are the principal cause of the classic kraft mill odour. They are generated by the reaction of sodium sulphide with some of the wood components. TRS is normally expressed as elemental sulphur.
TSS	Total suspended solids (qv). See suspended solids.
Turbidity	An attribute of water, causing scattering of light as it passes through the water. Usually caused by fine suspended particles, but may be caused by colour.
ug/L.	Micrograms per litre. Roughly speaking, a part per billion, or only one-thousandth of the strength of one mg/L.
USEPA	United States Environmental Protection Agency.
Washable soda	Refer to free soda.
Water quality criterion	(Plural: criteria) In the broad sense, a criterion is a number which may be used for judgement. In aquatic toxicology, w.q.c. commonly means the highest concentration which is not expected to cause an appreciable effect on an aquatic system or its users. The number is derived from available scientific data. There may be several sets of criteria for the same substance, e.g. for drinking water, industrial use, etc. These criteria always apply after dilution in the receiving water.
Water quality objective	Similar to water quality standard except that it is merely an expression of a desirable goal, and does not have the same force as a regulation, nor is there a penalty for transgression.
Water quality standard	A maximum concentration of a pollutant, or a maximum or minimum level of some characteristic such as pH, which is not to be transgressed in a body of water. These numbers are promulgated by a government or its agency by means of laws or regulations. They may or may not adhere closely to criteria.

White liquor	A liquid in the kraft process composed of the chemicals used in the digester to cook the wood chips. Primarily sodium sulphide and sodium hydroxide in aqueous solution.
White water	Abbreviated WW, a general term for water removed from a pulp suspension and containing a small amount of fibre and/or additives. On a paper machine, the excess water drained through the wire from the furnish. The use of the term "white water" usually implies low dissolved solids content, and a suspended solids content up to about 1000 mg/L, mostly of fine material. Always white or beige when white paper is produced, white water contains pigments when coloured paper is being made, and can be any colour.
Zero concentration	Zero concentration of any substance. is unattainable in to-day's world of rapid advances in analytical chemistry. A substance may be non-detectable (*qv*), but it is scientifically inaccurate to state that the concentration of any substance in an effluent sample is zero. The authors have, therefore, refrained from such terms as "zero concentration" or "elimination" of discharges of specific substances, unless they are qualified by adjectives such as "virtual", or in a special situation such as "a waste stream is totally eliminated".
Zero effluent	For the purpose of this report zero effluent is taken to mean elimination of liquid process effluent from a pulp or paper mill, without transferring an unreasonable load to the airshed or soil.

Unit conversion factors

Unless otherwise stated, all units in this report are stated in the Système International (SI).

Conversion factors between traditional and SI units are shown overleaf.

CONVERSION FACTORS

1 kg (kilogram)	= 2.205 pounds (lb.)	[lb x 0.4536 = kg]
1 t (tonne)	= 1.102 short (US) tons	[s. tons x 0.9072 = tonnes]
	= 0.9842 long (US) tons	[l. tons x 1.016 = tonnes]
1 ADt	= 0.9 oven dry tonnes pulp	
1 m (metre)	= 3.281 feet	[feet x 0.3048 = m]
1 km (kilometre)	= 0.6214 miles	[miles x 1.609 = km]
1 hectare	= 2.471 acres	[acres x 0.4047 = hectares]
1 km^2	= 100 hectares	
1 km^2	= 0.3861 square miles	[sq. mi. x 2.590 = km^2]
1 L (litre) of water	= approx. 1 kg	
1 m^3 of water	= 1000 L	= approx. 1 tonne
	= 35.31 cubic feet	[cubic feet x 0.02832 = m^3]
	= 220.0 Imp. gal.	[Imp. gal. x 0.004546 = m^3]
	= 264.2 U.S. gal.	[U.S. gal. x 0.003785 = m^3]
1 m^3/t	= 199.6 Imp. gal./short ton	[1000 gal/ton x 5.011 = m^3/t]
	= 239.7 U.S. gal./short ton	[1000 gal/ton x 4.171 = m^3/t]
1 kg/tonne	= 2 lb/short ton	[lb/ton x 0.5000 = kg/t]

Fractional Units

1 tonne	(metric tonne)	= 10^6 g	= 1000 kg
1 kg	(kilogram)	= 10^3 g	= 1000 g
1 g	(gram)	= 1 g	= 1000 mg
1 mg	(milligram)	= 10^{-3} g	= 1000 µg
1 µg	(microgram)	= 10^{-6} g	= 1000 ng
1 ng	(nanogram)	= 10^{-9} g	= 1000 pg
1 pg	(picogram)	= 10^{-12} g	= 1000 fg
1 fg	(femtogram)	= 10^{-15} g	= 1000 ag
1 ag	(attogram)	= 10^{-18} g	

Approximate Equivalents

1 g/L	= 1 g/kg	= 10^{-3} g/g	= "1 part per thousand"
1 mg/L	= 1 mg/kg	= 10^{-6} g/g	= "1 part per million"
1 µg/L	= 1 µg/kg	= 10^{-9} g/g	= "1 part per billion"
1 ng/L	= 1 ng/kg	= 10^{-12} g/g	= "1 part per trillion"
1 pg/L	= 1 pg/kg	= 10^{-15} g/g	= "1 part per quadrillion"